FINAL REPORT

EFFECTS OF FREEZING RATE, STORAGE TEMPERATURE, TEMPERATURE ABUSE AND STORAGE TIME ON SENSORY, CHEMICAL, AND YIELD PROPERTIES OF BULK GROUND BEEF WITH SOY

PREPARED FOR THE

U.S. ARMY NATICK RESEARCH AND DEVELOPMENT LABORATORIES
NATICK, MASSACHUSETTS 01760

AND THE

FOOD QUALITY ASSURANCE BRANCH
MARKET RESEARCH AND DEVELOPMENT DIVISION
AMS, USDA

BY THE

MEAT SCIENCE RESEARCH LABORATORY
AGRICULTURE RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE
BELTSVILLE, MARYLAND 20705

CONTACT PERSON: B. W. BERRY 301-344-1994

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PROJECT PERSONNEL

Meat Science Research Laboratory, Agricultural Research Service, USDA

Dr. R. W. Berry, Research Food Technologist
Mrs. Kathleen Leddy, Food Technologist
Ms. Marilyn Stanfield, Biological Laboratory Technician

University of Maryland

Mrs. Sue Douglass, Research Assistant
Mrs. Mary Dunn, Research Assistant
Mrs. Janice Callahan, Research Assistant
Dr. L. W. Douglass, Statistician
Dr. D. V. Schlimme, Associate Professor
Many students

U.S. Army Natick Research and Development Laboratories

Mr. John Secrist, Chief, Animal Products Group
Mr. Joe Smith, Food Technologist

Food Quality Assurance Branch, Market Research and Development Division, AMS, USDA

Mrs. Joan Luck Russ, Chief, FQAB, MRDD
Mr. E. Curtis Green, Agricultural Marketing Specialist

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OVERALL SUMMARY AND CONCLUSIONS

Fewer measured variables for bulk ground beef (as testified by fewer tables) were affected by the factors employed in the design of this study than for ground beef evaluated as patties or even roasts. Part of this reduction is most likely due to the absence of texture measurements by Instron and the need for evaluation of the bulk ground beef in the form of meat loaf; where many added ingredients are employed. Undoubtedly, the biggest finding for this product and the whole project for that matter was the occurrence of bright surface pigmentation or frozen bulk ground beef following nine-plus months of storage for product frozen to 0°F in 24 hours and subsequently stored at +20°F.

Aside from the above-mentioned freezing rate-final storage temperature effect on color and associated properties, freezing rate exerted its major effect on weight changes and moisture content. Throughout storage, thaw loss was highest for bulk ground beef frozen to 0°F in 96 hours and lowest for 0°F in 72 hours. It is conceivable that this difference was the result of some differences in the source and type of raw materials rather than freezing rate, per se. Percent moisture decreased for both 0°F in 72 and 96 hour frozen product with advancements in storage, but did not appreciably change for bulk ground beef frozen to 0°F in 24 and 48 hours. The color of thawed product following six months was lighter, the slower the rate of freezing.

Again, aside from the effects of +20°F storage on color and associated properties for bulk product frozen to 0°F in 24 hours, this temperature produced more surface discoloration than the other temperatures as storage advanced. The +20°F storage temperature produced more off-odor, more rancid and bitter flavors and greater weight loss during storage.

Longer storage time produced more off-odor but no real change in TBA values. Actually rancid flavor decreased between nine and twelve months as did juiciness. Longer storage slightly increased the weight loss of the bulk product and resulted in increased drip loss and decreased evaporative losses for cooked meat loaves.

Spectrophotometric measurements appear to indicate that the bright color on the surface of the frozen product frozen to 0°F in 24 hours and stored at +20°F is probably reduced myoglobin. It was interesting to note that upon thawing, the bulk surface lost this color. Certain bacteria have the capabilities of assisting in the reduction of metmyoglobin to reduced myoglobin. It would appear from the very high level of Brochothrix thermosphacta in the bulk product frozen to 0°F in 24 hours and stored at +20°F, that this organism perhaps has this pigment reducing function over time at temperatures around +20°F. At -10°F this pigment was not noted for this freezing rate (same formulation). It also appears that this organism is capable of producing under these packaging and storage conditions rather unpleasant cheesy odor and flavor that can be detected even in a highly seasoned meat loaf. Since this bright color obviously gives a false appraisal on the level of wholesomeness in this type of product, further work is certainly warranted on developing an understanding of the conditions responsible for this occurrence and the methods for controlling them.

In conclusion, it does not appear that the freezing rates employed in this study exert much of an effect on properties of bulk ground beef or meat loaf made from this product. If off-color and flavors are a problem, then storage at +20°F beyond six months cannot be recommended. There was

no clear evidence that -10°F storage temperature produces that much more improvement in product quality over 0°F. Also, the temperature abuse process did not play a major role in affecting results. It should be pointed out that a complete vacuum system for this type of product may extend storage life especially if it were necessary to store product at elevated temperatures.

INTRODUCTION

Freezing as a processing procedure is often a necessity for meat products that must undergo transcontinental and oceanic distribution or must be purchased far in advance of consumption due to supply, price and demand. These situations are frequently prevalent in USDA's purchase programs of ground beef for the school lunch program and DOD's procurement of meat products for military establishments. In order to maximize storage life, certain specifications regarding freezing rates, storage temperatures, packaging materials, raw material wholesomeness are applied.

One of the specifications required in the processing of meat products for government procurement deals with freezing rate. Prior to 1982, the requirement was that the product must be frozen to 10°F in 72 hr. Based on a variety of information sources, this requirement was changed in 1982 to 0°F in 72 hr, which reflects a faster rate of freezing. There were some representatives from industry who indicated that this faster freezing rate imposed hardships on their operations and placed them in non-competitive positions. However, there are others (processors and end-users) who maintain that faster freezing rates improve product quality.

In terms of defining what freezing rates were actually being used in industry, a nationwide survey of meat freezing operations was conducted. The survey indicated that a wide range in freezing rates was being practiced; some faster than the 0°F in 72 hr requirement, some slower. Thus, it was decided to evaluate for this project, four different freezing rates; 0°F in 24, 48, 72 and 96 hr. In preliminary studies, it was determined that wide ranges in time (often as much as 36-48 hr to reach 0°F) exist within a pallet load of meat in terms of when 0°F is achieved.

Thus, in order to achieve the uniformity in freezing rate required for this study, it was necessary to freeze product out of the boxes, spaced out on wire mesh racks.

Due to the lack of supportive literature to answer the effects of freezing rate on meat product characteristics, especially in conjunction with frozen storage time and temperature, this project was inaugurated. Four products (beef roasts, bulk ground beef with soy, ground beef patties with soy, ground beef patties without soy) were subjected to the above four freezing rates, two initial storage temperatures (0°F, -10°F), three final storage temperatures (0°F, -10°F, +20°F), temperature abuse of 4 hr at 35°F following 45 and 59 days of storage, and storage times of 0, 6, 9, 12, 18 and 24 months depending on the product. Evaluations included shelflife, microbial, sensory, instrumental texture, weight loss, chemical and cooking properties.

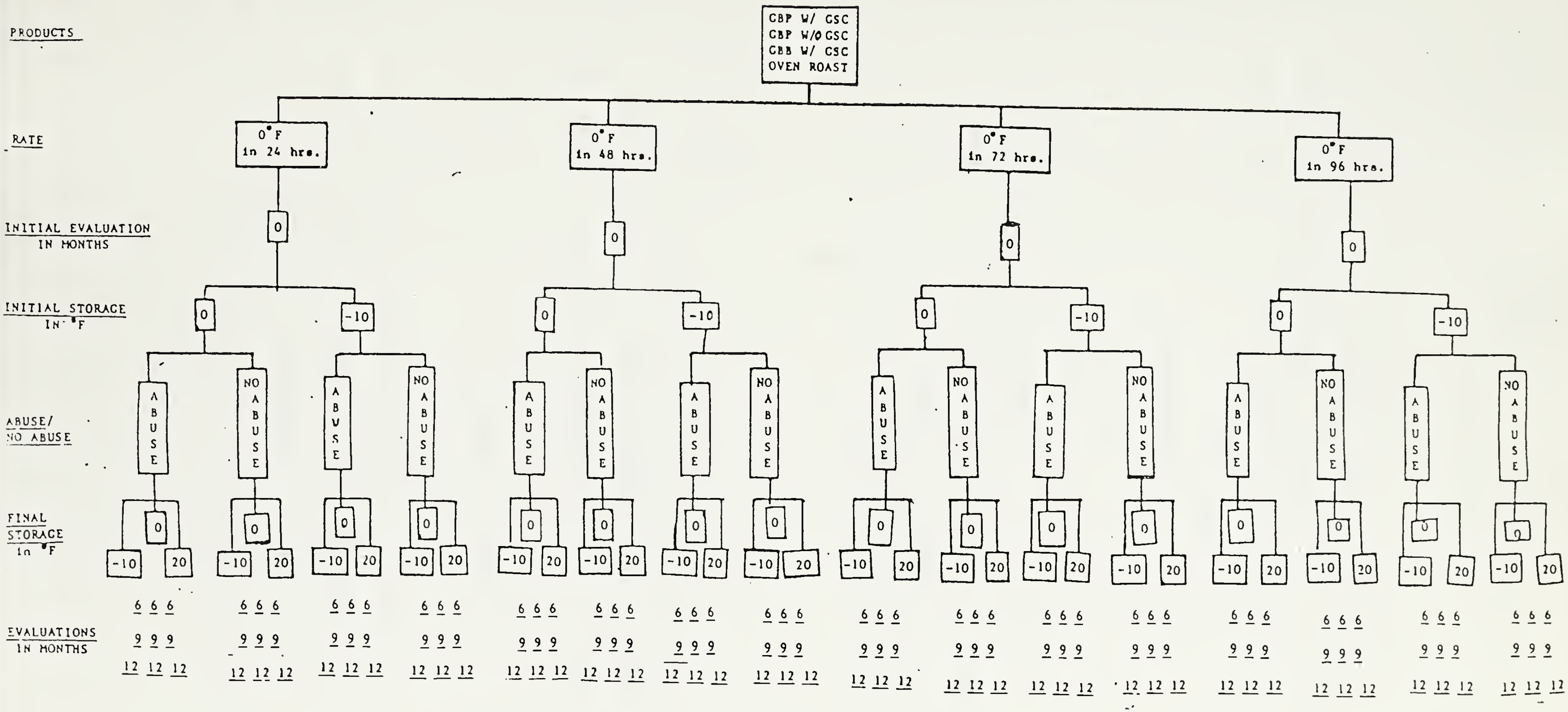
MATERIALS AND METHODS

Processing, freezing and storage

The overall project design is shown in Figure 1. Ground beef products were manufactured at a local meat processing establishment. Ground beef ingredients and product formulation conformed with USDA specification PPB 2120. Ground beef was extended with 20 percent rehydrated (2.5:1) soy protein concentrate (Procon 2060, A. E. Staley Co., Decatur, Illinois). Four batches (1100 pounds per batch) of the ground beef-soy product were processed on four different days, over a four-week period. The final fat content of each batch was adjusted to meet Federal interim specification PPB 2120.

Following the addition of soy to the formulation, all batches of product were bulk-packed in seven-pound bags (low density polyethylene, 2.0 ml thick). The oxygen permeability of the polyethylene film was 60 cc/100 in^2 when measured for 24 hrs at 25°C and 1 atmos. The bags were sealed with metal clamps, and boxed (eight per box). Boxes met USDA specification PPB 1163. The boxes were specifically constructed for the bulk ground beef product; dimensions were 20-1/4" x 16-1/4" x 6-1/2". After boxing, product was shipped to University of Maryland research freezers within four hours of processing. At the University bags were removed from boxes and individually placed on wire racks within the freezer. Copper constantin thermocouples, attached to temperature recording devices (Campbell Scientific 7, Digitec 1000) were inserted into the geometric centers of 10 representative bags in each of two freezers. Additional eight thermocouples were placed in key locations to monitor ambient air temperature. The freezer thermostat was set at a temperature, predetermined from preliminary trials, to achieve 0°F in 24, 48, 72 or 96 hours. Predetermined temperature adjustments were made at specific time

Figure 1. Project design.



MEATS FREEZING PROJECT

MEAT SCIENCE RESEARCH LABORATORY

For the U.S. Army Natick Research and Development Laboratories

January 1983

(FIGURE ▮)

KEY

GBP - Ground Beef Patties
GBB - Ground Beef Bulk
GSC - Granulated Soy Concentra
ABUSE - At days 45 and 59 4 hrs. at 85°F

intervals to achieve a given freezing rate. All thermocouple temperatures were monitored and recorded hourly throughout the freezing process.

After freezing, the frozen product was reboxed (six bags per box) and placed in storage at 0° or -10°F. After 45 and 60 days of storage at these temperatures, one-half of the boxed product in each rate received temperature abuse (80°F for four hours). The boxed product was laid on pallets outside of the laboratory to simulate temperature abuse encountered in normal military distribution channels. The temperature abuse slightly thawed the product surface to approximately 1/8 inch in depth. On day 60 of frozen storage, all product (abused and nonabused) was randomly divided and placed into one of three final storage temperatures +20°F, 0°F or -10°F.

Product evaluation

Product was evaluated initially fresh and frozen then at 6, 9 and 12 months' storage time. All product treatments were evaluated for yield, shelflife, sensory and chemical characteristics. Two boxes from each freezing rate-initial-final storage temperature combination were evaluated at each evaluation time. Two bags from each box were tagged and assigned to yield, sensory, shelflife and TBA analyses, while two other bags from each box were analyzed for expressible juice and percent fat and moisture. When a product treatment yielded sensory and shelflife characteristics indicative of product deterioration, past acceptable quality standards described by military personnel, that treatment was eliminated from the study.

Bags were identified for testing and labelled prior to thawing for 68-72 hours at 4°C. All analyses (except for some shelflife determinations) were conducted on thawed product. In order to distribute surface and interior portions, bags of thawed ground beef were drained of all purge, then mixed 30 sec at medium speed with an electric mixer (Hobart D-300) before the allocation of individual test samples.

Percent yield

One bag of ground beef per box, previously identified, was weighed fresh, after initial freezing, at the end of storage to measure product losses during freezing and storage, and following thawing.

Shelflife

Shelflife characteristics of frozen ground beef were evaluated by a trained team of staff members. Frozen bulk ground beef was evaluated within the bag for surface lean colors, discoloration and percent frost. Additionally, odor and interior lean colors were evaluated on thawed ground beef. Shelflife characteristics and scoring systems are described in Table 1.

Sensory evaluation

Bulk ground beef was evaluated as a meat loaf product prepared in accordance with a standardized formula provided by the U.S. Army (Table 2).

Selection and preliminary training of an eight-member panel followed procedures established for the sensory evaluation of ground beef (AMSA, 1978). Further refinement and training for the evaluation of a meat loaf

Table 1. Characteristics and scoring systems for shelflife evaluation

Surface Discoloration and Freezer Burn	Color of Lean[a]	Off Odor
7 = 0%	8 = light grayish red	4 = no off odor
6 = <10%	7 = very light cherry red	3 = slight off odor
5 = 11-25%	6 = moderately light cherry red	2 = moderate off odor
4 = 26-50%	5 = cherry red	1 = extreme off odor
3 = 51-75%	4 = slightly dark red	
2 = 76-90%	3 = moderately dark red	
1 = >90%	2 = dark red	
	1 = very dark red	
	0 = dark purplish black	

[a]Photographic scale adapted from Western Australian beef carcass classification system

Table 2. U.S. Army formulation for meat loaf

2268 g	Bulk ground beef with 20% soy
302.4 g	Bread crumbs
28.5 g	Salt
1.2 g	Pepper
75.6 g	Celery
9.5 g	Onion (dehydrated, minced)
189.0 g	Eggs (beaten)
23.8 g	Milk (non-fat dry)
216 ml	Water
227 ml	Tomato juice

Combine meat, bread crumbs, salt and pepper.
Mix one minute (Hobart D-300).
Add liquid ingredients, celery, onion, and eggs.
Mix one minute (Hobart D-300).
Bake 1-1/2 hr at 162.7°C (325°F).

product was accomplished through training sessions during which panelists evaluated meat loaf samples formulated with various levels of meat, soy, bread, salt and liquid ingredients.

Panelists evaluated samples (Table 3) for softness, juiciness, connective tissue, meat loaf flavor, cereal flavor, detectable other flavors and their intensities on an eight-point structured scale (8 = extremely soft, juicy, lacking connective tissue, and intense in flavor; 1 = extremely hard, dry, abundant in connective tissue, and just detectable in flavor intensity). Panelists received two pieces (2.54 cm^2), with all outside edges removed, per sample. They evaluated six samples per session; one session per day, and met twice per week. Panelists were instructed to drink warm water and eat melba toast between samples. Serving order was completely random within a session.

TBA

TBA values were determined in duplicate from two samples (10 g) from two bags of ground beef per box according to the distillation procedure of Tarladgis et al. (1960).

Expressible juice

Two samples (400-600 mg) from two bags per box were analyzed for expressible juice according to the procedure of Wierbecki and Deatherage (1958) with modifications described by Briskey et al. (1959).

Percent fat and moisture

Two samples (2.3 kg) from two bags of bulk ground beef per box were ground three times through a 0.3 cm plate according to AOAC procedures

Table 3. Meat Science Research Laboratory - Meat Loaf Form

SOFTNESS

8 - Extremely tender
7 - Very tender
6 - Moderately tender
5 - Slightly tender
4 - Slightly tough
3 - Moderately tough
2 - Very tough
1 - Extremely tough

JUICINESS

8 - Extremely juicy
7 - Very juicy
6 - Moderately juicy
5 - Slightly juicy
4 - Slightly dry
3 - Moderately dry
2 - Very dry
1 - Extremely dry

CONNECTIVE TISSUE AMOUNT

8 - None = 0%
7 - Practically none = 1-9%
6 - Traces = 10-19%
5 - Slight = 20-29%
4 - Moderate = 30-39%
3 - Slightly abundant = 40-49%
2 - Moderately abundant = 50-59%
1 - Abundant = 60%

MEAT LOAF FLAVOR INTENSITY

8 - Extremely intense
7 - Very intense
6 - Moderately intense
5 - Modestly intense
4 - Slightly intense
3 - Recognizable
2 - Barely recognizable
1 - Just detectable

DETECTABLE FLAVORS CODE

(In the off-flavor column, first indicate the number of the flavor component and behind it the intensity using the 8-point intensity scale).

1. Sour
2. Bitter
3. Metallic
4. Sweet
5. Rancid
6. Putrid
7. Salty
8. Other

CEREAL FLAVOR INTENSITY

8 - Extremely intense
7 - Very intense
6 - Moderately intense
5 - Modestly intense
4 - Slightly intense
3 - Recognizable
2 - Barely recognizable
1 - Just detectable

DETECTABLE FLAVORS INTENSITY

8 - Extremely intense
7 - Very intense
6 - Moderately intense
5 - Modestly intense
4 - Slightly intense
3 - Recognizable
2 - Barely recognizable
1 - Just detectable

(1980). Percent moisture was determined by the weight loss of two samples (5 g) after drying 8-12 hours in a vacuum oven (Precision 524). Fat content was determined by dried sample weight loss after 16 hours of extraction in petroleum ether.

Reflectance spectrophotometry

Objective measurements of frozen surface colors were obtained using a multipurpose reflectance spectrophotometer (Carey 14 Monochrometer) from six representative bags of the 24-10, 24+20 and 96+20 treatments. After standardization with a ceramic reflectance standard, reflectance measurements were taken from three different locations on each bag. Reflectance was recorded between 400 and 900 nanometers. Calculations were derived from reflectance data at selected wavelength ratios to quantify the percentages of myoglobin, oxymyoglobin and metmyoglobin pigments present in the meat samples.

Microbiological analysis

Five bags of bulk ground beef with soy (one each of 24-10 and 96+20; three bags of 24+20) were transported to a commercial laboratory for microbiological analysis.

Duplicate frozen surface samples (100 g) were cut from each bag to a depth of 1.25 cm. The remaining product in each bag was thawed 65 hours (4°C). At that time surface samples were again removed from each bag. Serial dilutions were made from each 50 gram subsample of meat (Gabis et al., 1985).

Quantitative and qualitative microbiolgical determinations were performed according to standard procedures outlined in Table A.

Table A. Microbiological Procedures

Quantitative Determinations	Media[a]	Plating Technique	Incubation	Confirmatory Tests
Aerobic mesophiles	Standard Methods Agar (SMA)	Pour Plates	35°C/48 hr	Gram stain
Aerobic psychrophiles	"	"	15°C/96 hr 4°C/10 D	Gram stain

Quantitative Determinations	Media[a]	Incubation	Confirmatory Tests
Staphylococcus aureus	Baird-Parker (B-P) Agar	20°C/72 hr 35°C/48 hr	Tube Coagulase Test
Lactobacillus	Lactobacillus Selection Agar (LBS) + 10% CO_2	20°C/72 hr	
Pseudomonas	Psuedomonas Isolation Agar (PIA)	15°C/72 hr	API Strips
Yeast cells	Potato Dextrose Agar (PDA) Acidified to pH = 3.5	20°C/5 D	
Brochothrix thermosphacta	Streptomycin Thallous Acetate Agar (STAA)	22°C/48 hr	MRVP Test, Carbohydrate fermentation, motility, Growth on STAA compared with ATCC 11509.

[a]All agar manufactured by Baltimore Biological Laboratories (BBL).

Characterization and identification

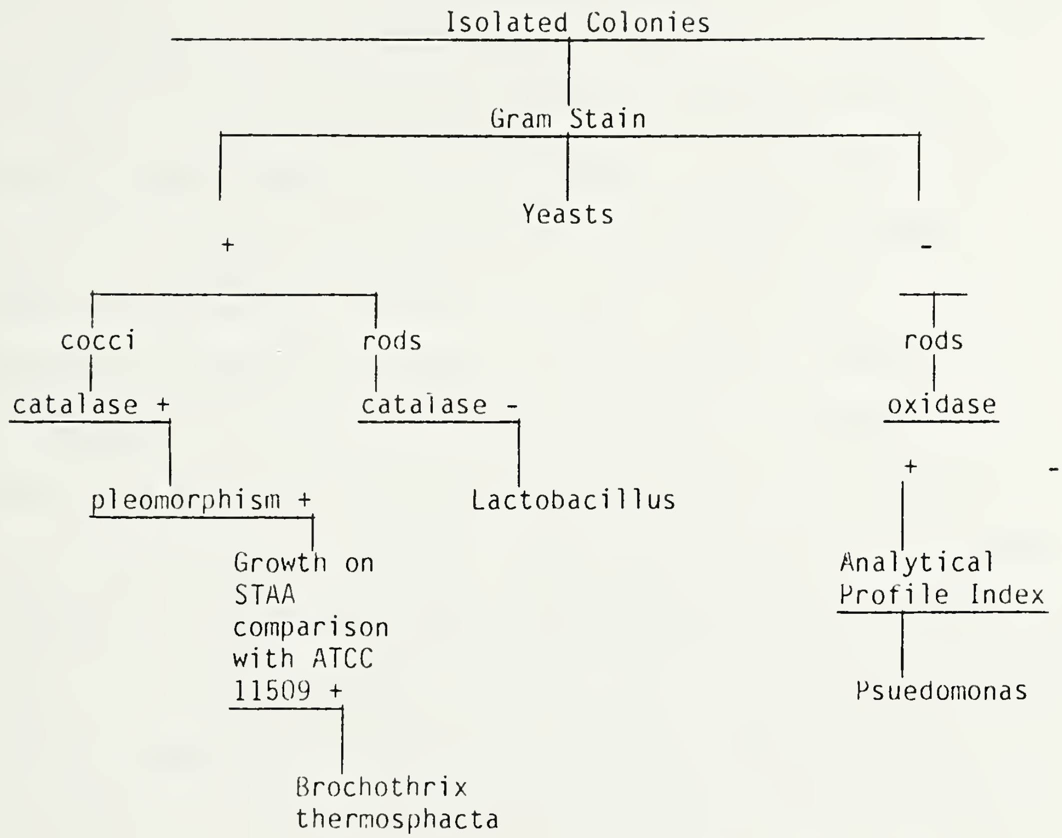
Six morphologically typical colonies from each aerobic plate at 4°C were isolated and identified according to established procedures (Figure 2). Tests to confirm and identify cultures followed procedures described in Bergey's Manual of Determinative Bacteriology (Buchanan and Gibbons, 1974.

Statistical analyses

Data were reduced and subjected to analyses of variance which included evaluations for freezing rate, initial storage temperature, final storage temperature and temperature abuse within storage times and all appropriate interactions. Storage time comparisons included all the above sources of variation in individual time comparisons involving values obtained immediately following freezing with a particular storage time. Also, adjacent storage times (six vs nine months, nine vs twelve months, etc.) were also compared.

The mean separation technique of Tukey's HSD was employed. In the case of color and flavors, Chi-square was utilized on frequency distributions for main effects and selected treatment combinations. At the beginning of each section on new variable data in the Results and Discussion, a general overall table illustrating means and standard deviations is provided. The following tables within the sections indicate the mean differences and standard errors.

Figure 2. Scheme for the identification of isolated colonies



Ref. Vanderzant, C. and Nickelson, K. 1969. A Microbiological Examination of Muscle Tissue of Beef, Pork and Lamb Carcasses. J. of Milk and Food Tech. 32:357.

RESULTS AND DISCUSSION

The freezing rate curves are given in Figure 3. The rate of temperature decline during early stages of freezing for the 0°F in 72 hour rate was closer to that of 0°F in 48 hour rate than would be desired. Table 4 illustrates the sensory panel's color score assignments to bulk bagged bulk ground beef prior to freezing. The overall Chi-square statistic is significant (P<.044) and thus indicates that some color differences were present just due to formulation differences. The product for the 0°F in 24 hour rate had more cherry red color, the 0°F in 48 hour rate product had more moderately light cherry red color, the product selected for the 0°F in 72 hour rate showed more very light cherry red color, while the bulk product used for the 0°F in 96 hour rate showed more dark red pigmentation. Immediately following freezing (Table 5), all of the freezing rates with the exception of 0°F in 72 hour showed an increase in dark red and very dark red color compared to before freezing. The 0°F in 72 hour rate product was scored as having more light grayish red and very light cherry red color than the other rates.

After six months of storage, a significant (P<.026) effect of final storage temperature was noted for color score frequencies (Table 6). The main difference was the prevalence of less light colored pigments and more dark pigments in bulk ground beef stored at +20°F vs the other two temperatures. Too some extent, this was also observed at nine months of storage (Table 7). However, there was a much higher frequency of cherry red color found for bulk ground beef frozen to 0°F in 24 hours and stored at +20°F. Further studies attempting to explain the occurrence of this pigment will be given in the surface discoloration section of the report.

Figure 3. Freezing curves to reach 0°F in 24, 48, 72 and 96 hours for ground beef patties with soy.

BULK GROUND BEEF WITH SOY

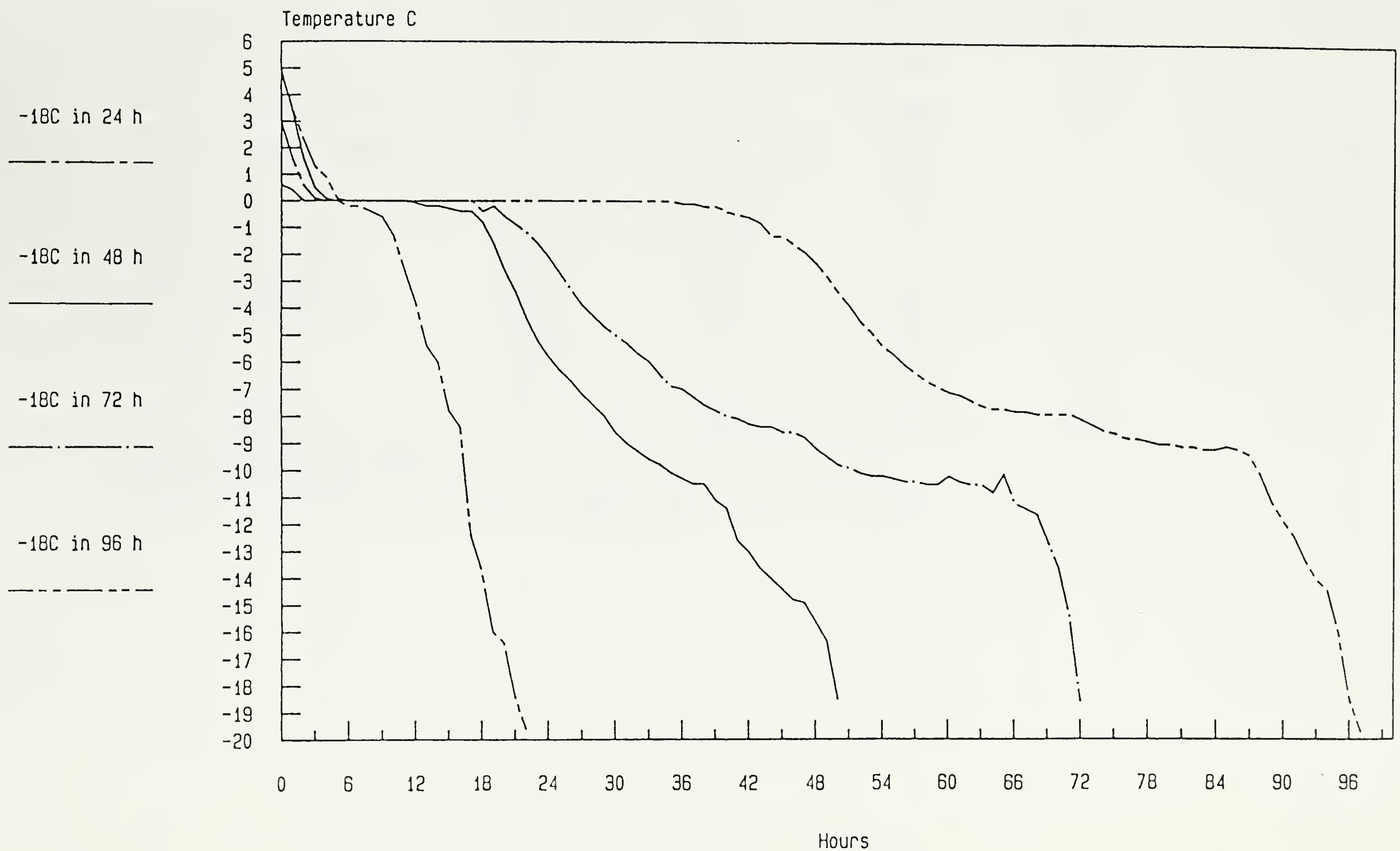


Table 4. Color scores assigned to the surface of bulk ground beef prior to freezing[a]

Color	Freezing rate, hours to 0°F			
	24	48	72	96
Light grayish red	13.42	14.72	18.94	14.78
Very light cherry red	20.13	21.89	24.24	19.57
Moderately light cherry red	17.45	18.49	12.88	15.65
Cherry red	8.05	1.89	1.52	3.48
Slightly dark red	15.44	16.23	16.67	15.65
Moderately dark red	16.11	18.49	18.94	15.22
Dark red	9.40	8.30	6.82	13.91
Very dark red	0.00	0.00	0.00	1.74

Chi-square = 33.24, $P<.044$.
[a]Values are percentages of scores assigned within rate of freezing.

Table 5. Color scores assigned to the surface of frozen bulk ground beef immediately following freezing and according to rate of freezing[a]

	Freezing rate, hours to 0°F			
Color	24	48	72	96
Light grayish red	3.17	10.53	24.24	1.88
Very light cherry red	15.08	24.21	32.32	13.75
Moderately light cherry red	18.25	8.42	17.17	18.13
Cherry red	0.79	1.05	1.01	1.25
Slightly dark red	4.76	12.63	13.13	10.63
Moderately dark red	7.94	15.79	7.07	8.75
Dark red	34.92	21.05	5.05	25.63
Very dark red	15.08	6.32	0.00	20.00

Chi-square = 115.74, $P<.0001$.

[a]Values are percentages of scores assigned within rate of freezing.

Table 6. Color scores assigned to the surface of frozen bulk ground beef according to final storage temperature following six months storage[a]

Color	Final storage temperature, °F		
	-10	0	+20
Light grayish red	5.92	5.71	1.96
Very light cherry red	18.64	20.12	15.29
Moderately light cherry red	19.23	18.02	15.29
Cherry red	3.55	3.60	1.96
Slightly dark red	15.98	15.92	13.33
Moderately dark red	15.38	15.62	18.82
Dark red	18.34	18.02	26.27
Very dark red	2.96	3.00	7.06

Chi-square = 26.0, $P<.026$.
[a]Values are percentages of scores assigned within a final storage temperature.

Table 7. Color scores assigned to the surface of frozen bulk ground beef according to freezing rate and final storage temperature following nine months storage[a]

		Color							
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Light grayish red	Very light cherry red	Moderately light cherry red	Cherry red	Slightly dark red	Moderately dark red	Dark red	Very dark red
24	-10	7.41	22.22	22.22	0.00	14.81	11.11	22.22	0.00
	0	2.22	20.00	20.00	0.00	15.56	13.33	22.22	6.67
	+20	3.81	14.29	17.14	10.48	19.05	13.33	17.14	4.76
48	-10	5.84	19.71	17.52	1.46	16.79	16.06	18.98	3.65
	0	3.94	20.47	16.54	2.36	16.54	18.11	18.90	3.15
	+20	5.11	19.71	13.14	2.19	15.33	20.44	21.90	2.19
72	-10	9.40	20.81	16.78	3.36	17.45	15.44	16.11	0.67
	0	6.85	21.23	19.18	1.37	16.44	17.81	14.38	2.74
	+20	10.77	20.77	11.54	0.00	3.85	20.77	26.92	5.38
96	-10	7.89	21.05	15.79	0.00	21.05	15.79	18.42	0.00
	0	2.70	21.62	18.92	0.00	10.81	18.92	21.62	5.41
	+20	1.69	20.34	13.56	1.69	20.34	11.86	23.73	6.78

Chi-square = 98.90, $P<.047$.

[a]Values are percentages of scores assigned within a freezing rate - final storage temperature combination.

In evaluating the changes in occurrence of selected pigments throughout storage, it can be observed that very light cherry red went up slightly for bulk product frozen to 0°F in 96 hour, while few changes were noted for this pigment according to other freezing rate-final storage temperature combinations (Table 8). The presence of cherry red color was generally low and variable, but was observable on the surface of bulk ground beef frozen to 0°F in 24 hours following six, nine and twelve months storage (Table 9). Dark red color increased with freezing by itself and was a commonly scored pigment at all storage periods (Table 10). With the exception of bulk ground beef frozen to 0°F in 24 hr, it was more frequently found on +20°F stored product compared to the other two storage temperatures.

Color scores given to the surface of thawed bulk ground beef immediately following freezing are very similar to those noted on the the surface of frozen bulk ground beef right after freezing (Table 11). The lighter pigments were more noticeable on the 0°F in 72 hour rate product and the darker pigments were less detectable compared to the other three freezing rates.

Color scores assigned to the interior of thawed bulk ground beef according to freezing rate and final storage temperature following six months storage are given in Table 12. Differences in frequencies appear to be associated more with freezing rate rather than storage temperature. The largest difference was noted in the higher frequency of dark red and lower frequency of cherry red in bulk ground beef frozen to 0°F in 72 vs the other three rates. In considering just the rate effect at this storage time on bulk interior colors (Table 13), it was noted that as the time

Table 8. Incidence of very light cherry red color on the surface of frozen bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

		Evaluation Time				
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	20.13	15.08			
	-10			17.72	22.22	18.48
	0			22.22	20.00	18.82
	+20			21.52	14.29	17.39
48	--	21.89	24.21			
	-10			16.67	19.71	16.16
	0			18.82	20.47	18.56
	+20			14.29	19.71	18.68
72	--	24.24	32.32			
	-10			21.51	20.81	20.00
	0			19.79	21.23	22.22
	+20			7.55	20.77	--
96	--	19.57	13.75			
	-10			18.42	21.05	20.69
	0			19.72	21.62	20.37
	+20			15.09	20.34	--

[a]Values are percentages of scores assigned within a freezing rate-final storage temperature-storage time combination.

Table 9. Incidence of cherry red color on the surface of frozen bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time				
		Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	8.05	0.79			
	-10			6.33	0.00	3.26
	0			3.70	0.00	4.71
	+20			5.06	10.48	9.78
48	--	1.89	1.05			
	-10			1.11	1.46	2.02
	0			0.00	2.36	3.09
	+20			0.00	2.19	5.49
72	--	1.52	1.01			
	-10			3.23	3.36	1.82
	0			6.25	1.37	3.70
	+20			0.00	0.00	--
96	--	3.48	1.25			
	-10			3.95	0.00	8.62
	0			4.23	0.00	3.70
	+20			1.89	1.69	--

[a]Values are percentages of scores assigned within a freezing rate-final storage temperature-storage time combination.

Table 10. Incidence of dark red color on the surface of frozen bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

		Evaluation Time				
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	9.40	34.92			
	-10			20.25	22.22	18.48
	0			17.28	22.22	21.18
	+20			21.52	17.14	16.30
48	--	8.30	21.05			
	-10			20.00	18.98	19.19
	0			20.00	18.90	20.62
	+20			25.71	21.90	21.98
72	--	6.82	5.05			
	-10			15.05	16.11	16.36
	0			16.67	14.38	20.37
	+20			32.08	26.92	--
96	--	13.91	25.63			
	-10			18.42	18.42	17.24
	0			18.31	21.62	22.22
	+20			28.30	23.73	--

[a]Values are percentages of scores assigned within a freezing rate-final storage temperature-storage time combination.

Table 11. Color scores assigned to the surface of thawed bulk ground beef according to freezing rate immediately following freezing[a]

Color	Freezing rate, hours to 0°F			
	24	48	72	96
Light grayish red	6.98	15.15	27.14	5.56
Very light cherry red	23.26	18.18	28.57	16.67
Moderately light cherry red	18.60	21.21	10.00	12.96
Cherry red	2.33	6.06	4.29	18.52
Slightly dark red	9.30	12.12	17.14	3.70
Moderately dark red	16.28	12.12	10.00	18.52
Dark red	16.28	15.15	2.86	20.37
Very dark red	6.98	0.00	0.00	3.70

Chi-square = 34.54 $P<.032$.
[a]Values are percentages of scores assigned within rate of freezing.

Table 12. Color scores assigned to the interior of thawed bulk ground beef according to freezing rate and final storage temperature following six months storage[a]

		Color							
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Light grayish red	Very light cherry red	Moderately light cherry red	Cherry red	Slightly dark red	Moderately dark red	Dark red	Very dark red
24	-10	7.69	23.08	21.79	15.38	20.51	10.26	1.28	0.00
	0	3.95	19.74	22.37	15.79	23.68	13.16	1.32	0.00
	+20	6.58	21.05	23.68	14.47	21.05	13.16	0.00	0.00
48	-10	10.11	20.22	19.10	7.87	17.98	13.48	11.24	0.00
	0	11.11	20.00	20.00	11.11	18.89	14.44	4.44	0.00
	+20	6.74	20.22	20.22	11.24	20.22	13.48	7.87	0.00
72	-10	12.84	20.18	17.43	3.67	15.60	15.60	14.68	0.00
	0	11.01	20.18	19.27	1.83	17.43	18.35	11.01	0.92
	+20	9.35	20.56	18.69	3.74	14.95	14.95	16.82	0.93
96	-10	6.82	22.73	22.73	7.95	22.73	14.77	2.27	0.00
	0	13.64	22.73	22.73	12.50	21.59	6.82	0.00	0.00
	+20	5.62	22.47	22.47	11.24	22.47	13.48	2.25	0.00

Chi-square = 112.26, P<.003.
[a]Values are percentages of scores assigned within a rate - final storage temperature combination.

Table 13. Color scores assigned to the interior of thawed bulk ground beef according to rate of freezing following six months storage[a]

Color	Freezing rate, hours to 0°F			
	24	48	72	96
Light grayish red	6.09	9.33	0.62	0.00
Very light cherry red	21.30	20.15	14.15	1.51
Moderately light cherry red	22.61	19.78	16.31	11.70
Cherry red	15.22	10.07	16.00	22.26
Slightly dark red	21.74	19.03	3.08	10.57
Moderately dark red	12.17	13.81	18.46	22.64
Dark red	0.87	7.84	20.31	22.64
Very dark red	0.00	0.00	11.08	8.68

Chi-square = 90.07, $P<.0001$.
[a]Values are percentages of scores assigned within rate of freezing.

progressed in freezing to 0°F, the presence of light colors became less and dark colors became greater. Slightly dark red made up a very low percentage of the scores assigned to bulk ground beef frozen to 0°F in 72 hr. Generally, following nine months of storage, regardless of freezing rate, there was less moderately light cherry red and cherry red color and more moderately dark red and dark red color than what was noted after six months storage (Table 14). The use of +20°F storage tended to elevate the appearance of very light cherry red and moderately dark red, while reducing the presence of slightly dark red.

Following nine months storage, temperature abused products (thawed surface) displayed more moderately light cherry red and less very light cherry red and moderately dark red than nonabused product (Table 15). At twelve months, +20°F storage produced more of the darker pigments than -10 and 0°F storage when evaluations occurred on the surface (Table 16). Approximately the same situation regarding the influence of the temperature abuse on thawed surface color occurred at twelve months as nine months of storage (Table 17).

Generally, very light cherry red was a prevalent pigment on thawed bulk ground beef surfaces throughout storage when product was held at +20°F. However, lower values were found for product frozen to 0°F in 72 hr and stored six months (Table 18). Cherry red color increased as a result of freezing and remained as a lower frequency of detection pigment throughout storage (Table 19). Dark red color was noted at a high percentage in some treatments, but followed no logical trend respective to freezing rate and final storage temperature (Table 20).

Table 14. Color scores assigned to the surface of thawed bulk ground beef according to freezing rate and final storage temperature following nine months storage[a]

		Color								
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Light grayish red	Very light cherry red	Moderately light cherry red	Cherry red	Slightly dark red	Moderately dark red	Dark red	Very dark red	Blackish purple
24	-10	7.23	19.23	15.66	2.41	18.07	18.07	12.05	0.00	7.23
	0	2.75	21.10	16.51	1.83	17.43	17.43	15.60	0.92	6.42
	+20	7.93	22.56	14.63	3.05	14.63	18.90	10.98	2.44	4.88
48	-10	11.48	22.13	11.48	0.82	21.31	19.67	13.11	0.00	0.00
	0	9.92	22.31	12.40	0.83	19.83	19.01	14.88	0.83	0.00
	+20	4.79	27.54	16.17	0.00	11.38	24.55	14.97	0.60	0.00
72	-10	11.48	22.95	12.30	2.46	19.67	18.85	10.66	1.64	0.00
	0	12.60	21.26	14.96	2.36	17.32	18.90	12.60	0.00	0.00
	+20	10.98	31.79	8.09	0.00	8.09	25.43	15.03	0.58	0.00
96	-10	10.84	21.69	13.25	7.23	20.48	20.48	6.02	0.00	0.00
	0	7.27	22.73	17.27	1.82	19.09	19.09	12.73	0.00	0.00
	+20	7.48	29.91	14.02	1.87	13.08	22.43	10.28	0.93	0.00

Chi-square = 162.87, P<.001.

[a]Values are percentages of scores assigned within a freezing rate - final storage temperature combination.

Table 15. Color scores assigned to the surface of thawed bulk ground beef according to temperature abuse following nine months storage[a]

	Temperature Abuse	
Color	T	N
Light grayish red	8.50	9.85
Very light cherry red	23.12	29.55
Moderately light cherry red	14.71	9.09
Cherry red	2.21	0.00
Slightly dark red	16.18	15.53
Moderately dark red	19.53	25.38
Dark red	13.15	10.61
Very dark red	0.90	0.00
Blackish purple	1.72	0.00

Chi-square = 26.65, $P<.0008$.
[a]Values are percentages of scores assigned within temperature and nontemperature abused product.

Table 16. Color scores assigned to the surface of thawed bulk ground beef according to final storage temperature following twelve months storage[a]

Color	Final storage temperature, °F -10	0	+20
Light grayish red	5.76	6.81	4.27
Very light cherry red	21.52	21.67	29.06
Moderately light cherry red	17.27	17.65	8.55
Cherry red	4.24	2.48	0.00
Slightly dark red	19.09	18.89	15.38
Moderately dark red	18.18	18.89	23.93
Dark red	13.94	13.62	17.09
Very dark red	0.00	0.00	1.71

Chi-square = 33.94, P<.037

[a]Values are percentages of scores assigned within final storage temperature.

Table 17. Color scores assigned to the surface of thawed bulk ground beef according to temperature abuse following twelve months storage[a]

Color	Temperature Abuse T	Temperature Abuse N
Light grayish red	6.28	4.27
Very light cherry red	21.59	29.06
Moderately light cherry red	17.46	8.55
Cherry red	3.37	0.00
Slightly dark red	18.99	15.38
Moderately dark red	18.53	23.93
Dark red	13.78	17.09
Very dark red	0.00	1.71

Chi-square = 26.02, P<.0005.

[a]Values are percentages of scores assigned within temperature (T) and nontemperature (N) abused product.

Table 18. Incidence of very light cherry red color on the surface of thawed bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

		Evaluation Time				
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	20.13	23.26			
	-10			20.83	19.28	22.67
	0			22.97	21.10	23.29
	+20			28.81	22.56	29.03
48	--	21.89	18.18			
	-10			18.60	22.13	20.45
	0			19.75	22.31	20.09
	+20			24.24	27.54	29.09
72	--	24.24	28.57			
	-10			19.44	22.95	21.51
	0			21.57	21.26	22.22
	+20			18.18	31.79	--
96	--	19.57	20.37			
	-10			18.35	21.69	21.82
	0			19.80	22.73	20.65
	+20			24.10	29.91	--

[a]Values are percentages of scores assigned within a freezing rate-final storage temperature-storage time combination.

Table 19. Incidence of cherry red color on the surface of thawed bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

		Evaluation Time				
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	8.05	2.33			
	-10			4.17	2.41	0.00
	0			2.70	1.83	1.37
	+20			1.69	3.05	0.00
48	--	1.89	6.06			
	-10			2.33	0.82	4.55
	0			3.70	0.83	3.45
	+20			1.52	0.00	0.00
72	--	1.52	4.29			
	-10			1.85	2.46	7.53
	0			0.00	2.36	3.33
	+20			1.52	0.00	--
96	--	3.48	3.70			
	-10			5.50	7.23	3.64
	0			2.97	1.82	2.17
	+20			0.00	1.87	--

[a]Values are percentages of scores assigned within a freezing rate-final storage temperature-storage time combination.

Table 20. Incidence of dark red color on the surface of thawed bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

		Evaluation Time				
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	9.40	16.28			
	-10			9.72	12.05	20.00
	0			13.51	15.60	17.81
	+20			11.86	10.98	16.13
48	--	8.30	15.15			
	-10			18.60	13.11	11.36
	0			17.28	14.88	12.64
	+20			19.70	14.97	18.18
72	--	6.82	2.86			
	-10			14.81	10.66	10.75
	0			17.65	12.60	10.10
	+20			21.21	15.03	--
96	--	13.91	16.67			
	-10			12.84	6.02	14.55
	0			8.91	12.73	15.22
	+20			14.46	10.28	--

[a]Values are percentages of scores assigned within a freezing rate-final storage temperature-storage time combination.

General information pertaining to scores for surface discoloration are given in Table 21. Freezing in itself increased the percentage of the bulk ground beef surface deemed discolored. With storage, the use of +20°F tended to create more discoloration with the exception of product frozen to 0°F in 24 hours, where the opposite occurred.

At six months of storage, the bulk ground beef stored at +20°F possessed more surface discoloration than that exposed to the other two temperatures only for product originally frozen to 0°F in 72 hours (Table 22). However, among product stored at +20°F, only bulk ground beef frozen to 0°F in 24 hours had less discoloration. Differences in surface discoloration were apparent before initiation of freezing and thus data adjustments were necessary (Table 23). Following the adjustments, discoloration scores following six months storage revealed that bulk product frozen to either 0°F in 48 or 96 hours had less discoloration than bulk samples held at +20°F and originally frozen to 0°F in 72 hours.

Following nine months of storage, numerous differences ($P<.05$) existed for surface discoloration on frozen bulk ground beef (Table 24). The main reason for the interaction in this table was the lesser amount of discoloration noted for +20°F stored product compared to the other two temperatures, when the freezing rate was 0°F in 24 hours, while the opposite was true for the other three rates. Also, for +20°F stored product, temperature abuse resulted in less discoloration (0°F in 24 hour freezing rate). Adjusting the values for differences prior to freezing made some of the differences between +20°F and 0 and -10°F stored product nonsignificant ($P>.05$). However, generally the adjustments were small (Table 25).

Table 21. General table illustrating sensory scores for surface discoloration on frozen bulk ground beef throughout storage and according to final storage temperature and rate of freezing - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		4.88 ± .48	5.37 ± .55	6.28 ± .46	5.38 ± .53
Immediately following freezing, 1 day		2.65 ± .60	3.56 ± .67	3.61 ± .66	4.27 ± .73
6 months	-10T	2.94 ± .42	3.84 ± .62	4.12 ± .67	3.62 ± .72
	0T	3.19 ± .62	3.30 ± .57	3.56 ± .68	3.25 ± .86
	20T	3.04 ± 1.06	2.30 ± .67	1.08 ± .31	2.19 ± .40
9 months	-10T	1.91 ± .00	3.46 ± .50	3.35 ± .68	2.28 ± .52
	0T	2.16 ± .48	2.94 ± .57	2.90 ± .64	2.41 ± .53
	20T	4.46 ± .65	2.0 ± .72	1.09 ± .25	1.84 ± .86
	20N	3.76 ± .52	2.09 ± .00	.95 ± .00	1.41 ± .55
12 months	-10T	2.90 ± 1.01	2.94 ± .51	3.0 ± .60	3.08 ± .67
	0T	2.76 ± .95	2.81 ± .61	2.92 ± .79	2.92 ± .67
	20N	4.50 ± .51	2.52 ± .60	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 22. Interaction effect of final storage temperature and rate of freezing on sensory scores for surface discoloration in frozen bulk ground beef stored six months

Final Storage Temperature, °F	Freezing rate, hours to 0°F 24	48	72	96
-10	2.94 ± 0.23bc	3.84 ± 0.23ab	4.12 ± 0.23a	3.62 ± 0.23ab
0	3.19 ± 0.23abc	3.3 ± 0.23abc	3.56 ± 0.23ab	3.25 ± 0.23abc
+20	3.04 ± 0.23abc	2.3 ± 0.23cd	1.08 ± 0.23d	2.19 ± 0.23bcd

abc Any mean comparisons with the same letter are not different ($P > .05$).
Mean ± S.E.

Table 23. Interaction effect of final storage temperature and freezing rate on sensory scores for surface discoloration on frozen bulk ground beef stored six months -- data adjusted for differences prior to freezing

Final Storage Temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	3.54 $\pm$ .23ab	3.94 $\pm$ .23a	3.32 $\pm$ .23abc	3.72 $\pm$ .23a
0	3.79 $\pm$ .23a	3.40 $\pm$ .23abc	2.76 $\pm$ .23abc	3.35 $\pm$ .23abc
+20	3.64 $\pm$ .23a	2.40 $\pm$ .23bc	0.28 $\pm$ .23d	2.29 $\pm$ .23c

abcd Any mean comparison with different letters is different (P>.05).
Mean $\pm$ S.E.

Table 24 . Interaction effect of initial storage temperature, final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef following nine months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10T	1.91 ± .039hi	3.71 ± .039b	3.85 ± .039b	2.41 ± .039fg
	0T	2.42 ± .039fg	3.25 ± .039c	2.93 ± .039de	2.66 ± .039ef
	20T	4.33 ± .039a	2.21 ± .039gh	1.08 ± .039j	2.53 ± .039f
	20N	3.76 ± .039b	2.09 ± .039hi	1.00 ± .039j	.91 ± .039j
0	-10T	1.91 ± .039hi	3.21 ± .039cd	2.86 ± .039e	2.16 ± .039gh
	0T	1.91 ± .039hi	2.62 ± .039ef	2.88 ± .039e	2.16 ± .039gh
	20T	4.58 ± .039a	1.79 ± .039i	1.10 ± .039j	1.16 ± .039j
	20N	3.76 ± .039b	2.09 ± .039hi	.91 ± .039j	1.91 ± .039hi

abcdefghij Any mean comparisons with different letters are different ($P<.05$); Mean ± S.E.;
T = Temperature abused; N = Not temperature abused.

Table 25. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef following nine months storage -- data adjusted for differences prior to freezing

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	2.51 ± .25cdef	3.81 ± .18abc	3.05 ± .18bcde	2.51 ± .25cdef
	0	3.02 ± .18bcde	3.35 ± .18bcd	2.13 ± .18defg	2.76 ± .25cde
	20T	4.93 ± .18a	2.31 ± .18defg	.28 ± .18h	2.63 ± .25cdef
	20N	4.36 ± .25ab	2.20 ± .25defg	.20 ± .18h	1.00 ± .25gh
0	-10	2.51 ± .25cdef	3.31 ± .18bcde	2.06 ± .18defg	2.26 ± .25defg
	0	2.51 ± .25cdef	2.73 ± .18cde	2.07 ± .18defg	2.26 ± .25defg
	20T	5.18 ± .18a	1.90 ± .18efg	.30 ± .18h	1.26 ± .25fgh
	20N	4.36 ± .25ab	2.20 ± .25cdef	.10 ± .18h	2.01 ± .25defg

abcdefgh Any mean comparison with different letter is different ($P<.05$).
Mean ± S.E. T = temperature abused; N = not temperature abused.

In an effort to determine the cause of the rather unexpected bright red color (or at least less discolored appearance) of the bulk ground beef originally frozen to 0°F in 24 hours and stored at +20°F, spectrophometric and microbial studies were undertaken. Various K/S values were obtained at wave lengths known to show differences between myoglobin, oxymyoglobin and metmyoglobin. Three products were selected for these evaluations: product frozen to 0°F in 24 hours and stored at +20°F, product frozen to 0°F in 24 hours and stored at -10°F (thus same formulation) and product frozen to 0°F in 96 hours and stored at +20°F (slower freezing rate, different formulation, but same final storage temperature). Also, new bulk ground beef containing fat and soy at the same level as products in the study were processed and placed in the same packaging material (low density polyethylene, 2.0 mil thickness) prior to determining spectrophetom tric measurements. Following oxygenation for 20 min, readings were taken (MbO) and then again following 48 hours of storage at 5°C (MMb). These values were used as references.

K/S 507 over K/S 525 values revealed that bulk ground beef frozen to 0°F in 24 hours and stored at +20°F was closer to MbO than the other two products which were close to the value obtained for MMb (Table 26). The same can be said for K/S 572 over K/S 525, K/S 630 over K/S 525 and K/S 614 over K/S 525. K/S 582 over K/S 525 was less clear but did show a close association between the MMb standard and product frozen to 0°F in 96 hours and stored at +20°F.

Curves given in Figures 4 and 5 indicate that the pigment observed for the product frozen to 0°F in 24 hours and then finally stored at +20°F (-7°C) is not MbO (which would be hard to believe under these storage

Table 26. Spectrophotometric reflectance measurements on the surface of frozen bulk ground beef following nine months storage

Freezing Rate, hours to 0°F	Final Storage Temperature, °F	K/S 507 / K/S 525	K/S 572 / K/S 525	K/S 630 / K/S 525	K/S 614 / K/S 525	K/S 582 / K/S 525
24	20	.80	1.06	.23	.32	.87
24	-10	.96	.89	.36	.38	.89
96	20	.94	.81	.30	.37	.70
MbO	Standard	.75	1.34	.14	.18	1.42
MMb	Standard	1.11	.70	.55	.54	.68

Figure 4. Spectrophotometric reflectance curves (K/S) for the surface of bulk ground beef in the oxygenated (MbO) and oxidized (MMb) form.

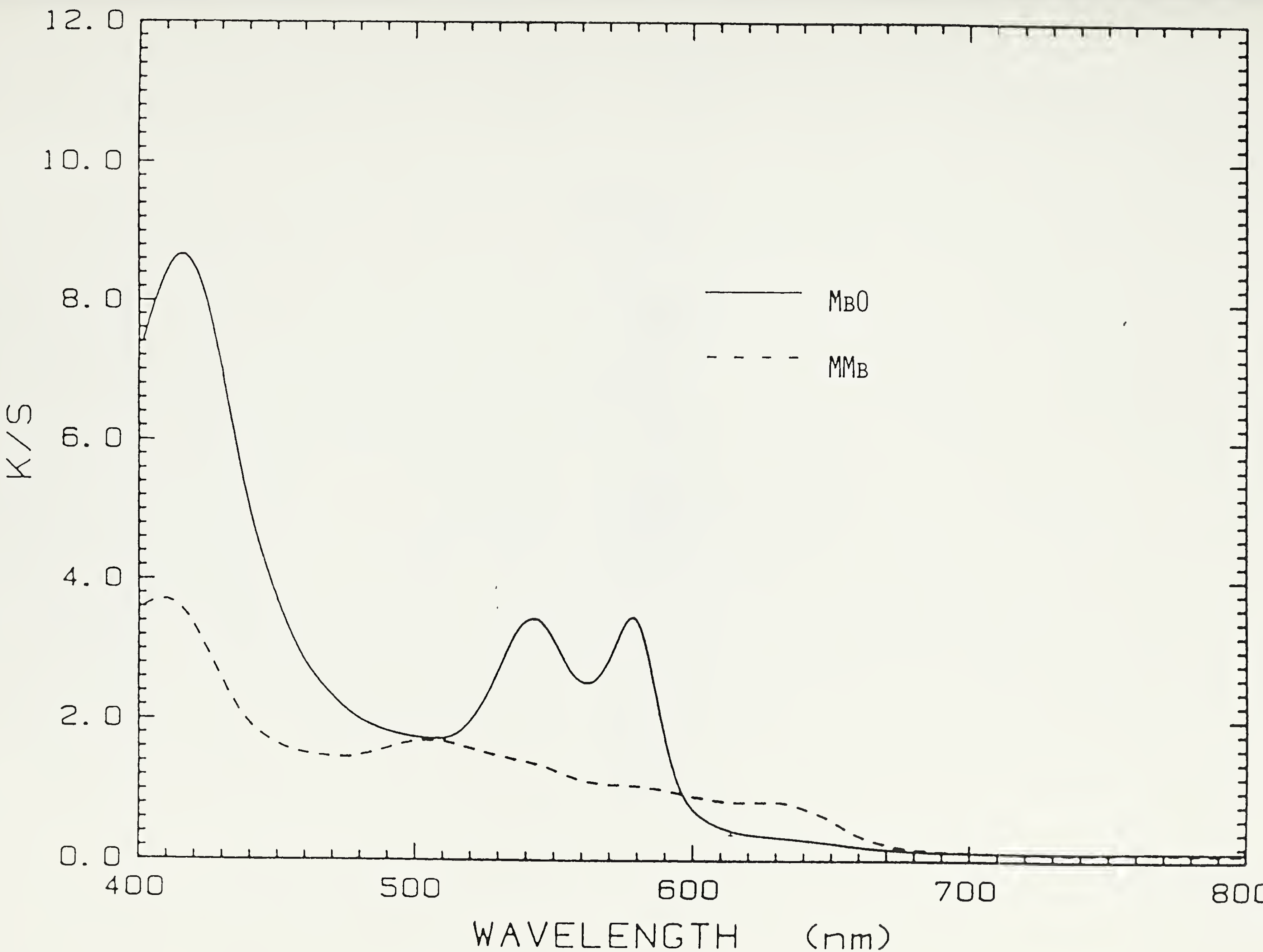
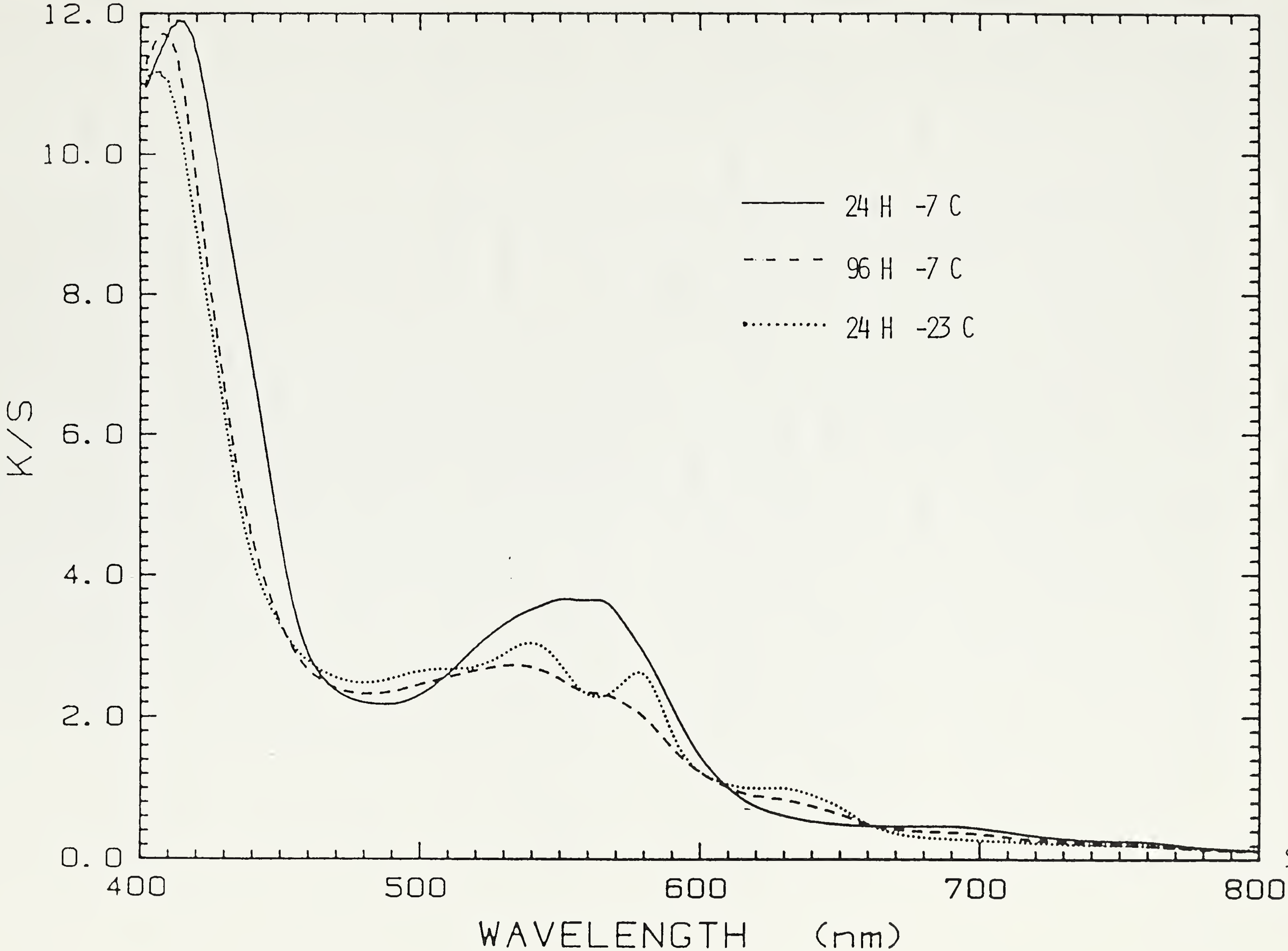

12.0
10.0
8.0
6.0
4.0
2.0
0.0
K/S
400
500
600
700
800
WAVELENGTH (nm)
MBO
MMB

Figure 5. Spectrophotometric reflectance curves (K/S) for the surface of frozen bulk ground beef frozen: to 0°F in 24 hours and finally stored at +20°F (-7°C), to 0°F in 96 hours and finally stored at +20°F (-7°C) and to 0°F in 24 hours and stored at -10°F (-23°C).


12.0
10.0
8.0
6.0
4.0
2.0
0.0
K/S
400
500
600
700
800
WAVELENGTH (nm)
24 H -7 C
96 H -7 C
24 H -23 C

temperatures and times) but rather most likely a reduced myoblobin. Several studies have been conducted to experimentally create reduced Mb; however, it has not been shown to occur under frozen storage conditions. The curves indicate that the majority of the pigment present for the bulk ground beef frozen to 0°F in 96 hours and stored at +20°F was MMb, which was also true for the product frozen to 0°F in 24 hours and stored at -10°F; however, this product did contain some MbO.

Efforts to determine a microbial cause of this Mb reducing activity are depicted in the next set of tables. For both frozen and thawed product, the highest aerobic plate counts were found at the lower incubation temperatures (Table 27). This is not too surprising considering the length of frozen storage. Bulk ground beef frozen to 0°F in 96 hours and stored at +20°F had the highest counts.

Colony isolates were obtained from the plates incubated at 4°C for further classification of specific organisms. Information given in Table 28 reflects the predominent organisms for the three treatments tested. Brochothrix termosphacta was the major bacteria isolated from bulk ground beef frozen to 0°F in 24 hours and finally stored at +20°F, while Pseudomonas was the most frequently recovered microorganism found growing on bulk ground beef frozen to 0°F in 24 hours and stored at -10°F (same formulation). Apparently the lower temperature is very conducive to the destruction of Brochothrix thermosphocta. Yeast made up the most frequently found orginism on bulk ground beef frozen to 0°F in 96 hours and stored at +20°F. Occasionally surface mold could be seen on this product under frozen storage where the bag had become unattached from the product.

Table 27. Aerobic plate counts ($\log_{10}$/g) from frozen and thawed bulk ground beef following nine months storage

Freezing Rate, hours to 0°F	Final Storage Temperature, °F	Incubation temperature, 0°F	Frozen product			Thawed product		
			4 C	15 C	35 C	4 C	15 C	35 C
24	20		6.3	5.9	4.8	7.9	7.9	6.4
24	-10		6.2	6.4	5.5	7.7	7.7	7.2
96	20		7.3	7.4	5.7	8.1	8.6	7.0

Table 28. Numbers of specific microorganisms obtained from isolates derived from bulk ground beef following nine months storage[a]

Freezing Rate, hours to 0°F	Final Storage Temperature, °F	Microorganism =	Brochothrix thermosphacta		Pseudomonas		Yeasts	
		Product Form =	Frozen	Thawed	Frozen	Thawed	Frozen	Thawed
24	20		20/23	22/24	0/23	0/24	3/23	0/24
24	-10		3/12	2/12	9/12	9/12	0/12	0/12
96	20		2/12	2/12	0/12	0/12	10/12	9/12

[a]All counts obtained from 4°C incubation. No/No indicates the number of isolates per total number isolates for a freezing rate-final storage temperature combination being a particular microorganism.

Additional studies on incubating isolates from product frozen to 0°F in 24 hour and stored at +20°F at different incubation temperatures are presented in Table 29. As incubation temperatures were elevated to 15 or 35°C, Brochothrix thermosphacta became a much lower or nonexistent member of the microbial profile. Lactobacillus and Staphylococcus increased with the higher incubation temperatures. Thus, this table serves to identify fairly completely that the microbial profile of this product is largely Brochothrix thermospacta, Lactobacillus and Staphylococcus. Since Brochothrix thermospacta was rarely found on the other two tested products (24 -10, 96 +20), the possibility exists at least for some relationship between the Mb reducing activity and the presence of this organism.

Following twelve months of storage, this pigment (or less discoloration) was again noted for bulk ground beef frozen to 0°F in 24 hours and finally stored at +20°F (Table 30). Only the 24 and 48 hour freezing rates could be compared over all three storage temperatures since the +20°F temperature was eliminated for the 0°F in 72 and 96 hour rates due to severe deterioation. Also, at twelve months, for just the 24 and 48 hour freezing rates, the use of +20°F temperature produced less discoloration than 0°F if 0°F was the initial storage temperature (Table 31). In comparing initial and final storage temperatures over all rates following twelve months (the +20°F temperature had to be dropped) for product finally stored at 0°F, -10°F initial storage produced less discoloration (Table 32).

Comparisons of storage time advancements with product immediately post-freezing revealed more discoloration with storage time increases (Table 33). For all freezing rates, freezing produced discoloration on the

Table 29. Numbers of specific microorganisms (different incubation temperatures) obtained from isolates derived from bulk ground beef frozen to 0°F in 24 hours and stored at +20°F following nine months storage[a]

Incubation temperature, 0°C	Product Form =	*Brochothrix thermosphacta* Frozen	*Brochothrix thermosphacta* Thawed	*Lactobacillus* Frozen	*Lactobacillus* Thawed	*Staphylococcus* Frozen	*Staphylococcus* Thawed
4		20/23	22/24	0/23	0/24	0/23	0/24
15		2/12	4/12	3/12	1/12	5/12	0/12
25		0/12	0/12	6/12	7/12	5/12	3/12

[a]No/No indicates the number of isolates per total number isolates for a product form-incubation temperature combination being a particular microorganism.

Table 30. Interaction effect of final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef following twelve months storage

Final storage temperature, °F	Freezing rate, hours to 0°F	
	24	48
-10T	2.90 ± .24b	2.94 ± .24b
0T	2.76 ± .24b	2.81 ± .24b
20N	4.5 ± .24a	2.52 ± .24b

ab Any mean comparison with the same letter is not different (P>.05); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

Table 31. Interaction effect of final storage temperature and initial storage temperature on sensory scores for surface discoloration on frozen bulk ground beef following twelve months storage

Final storage temperature, 0°F	Initial storage temperature, °F	
	-10	0
-10T	2.53 ± .24ab	3.31 ± .24ab
0T	3.15 ± .24ab	2.42 ± .24b
20N	3.37 ± .24ab	3.65 ± .24a

ab Any mean comparison with the same letters is not different (P>.05); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

Table 32. Interaction effect of final storage temperature and initial storage temperature on sensory scores for surface discoloration on frozen bulk ground beef following twelve months storage

Final storage temperature, 0°F	Initial storage temperature, °F	
	-10	0
-10	2.89 ± .18ab	3.07 ± .18ab
0	3.28 ± .18a	2.42 ± .18b

ab Any mean comparisons with the same letters are not different ($P>.05$); mean ± S.E.

Table 33. Effect of various storage time comparisons on sensory scores for surface discoloration on frozen bulk ground beef

Evaluation times	
Immediately following freezing, 1 day	6 months
3.52 ± .17a	3.04 ± .17b
Immediately following freezing, 1 day	9 months
3.52 ± .094a	2.43 ± .094b
Immediately following freezing, 1 day	12 months
3.52 ± .18a	2.92 ± .18b

ab Means on the same line with different letters are different ($P<.05$); Mean ± S.E.

frozen surfaces (Table 34). Following freezing, there was less discoloration on surfaces of product subjected to slower freezing. Adjusting these results for differences noted pre-freezing resulted in the 0°F in 72 hour freezing rate having more discoloration than the other products (Table 35). Comparisons of six-month treatment categories with values for discoloration immediately following freezing show that even then, +20°F temperature did not accelerate discoloration for product frozen to 0°F in 24 hours (Table 36). The same was true for bulk ground beef frozen to 0°F in 72 hours. Adjusting these comparisons for differences pre-freezing did not greatly alter the significant ($P<.05$) differences (Table 37).

Comparisons between the various treatment levels at nine months for frozen surface discoloration and also that found right after freezing are shown in Table 38. There are several major reasons for the interaction. These are: (1) less discoloration on +20°F stored product than 0 and -10°F stored product if the freezing rate was 0°F in 24 hours, (2) less discoloration on +20°F stored product than immediately following freezing if the freezing rate was 0°F in 24 hours, (3) more surface discoloration on +20°F stored product than -10 and 0°F if the freezing rate was 0°F in 72 hours, and (4) all treatments at nine months having more surface discoloration than right after freeing if the freezing rate was 0°F in 96 hours. About the only change in these findings from adjusting the data for differences prior to freezing (Table 39) was the greater discoloration for most +20°F stored bulk ground beef _vs_ the other temperatures for freezing to 0°F in 48 hours. In evaluating the time (six, nine months) final storage temperature and freezing rate interaction (Table 40), at six months for just 0°F in 24 hour frozen product, scores for surface discoloration

Table 34. Interaction effect of storage time (before freezing, immediately following freezing, 1 day) and freezing rate on sensory scores for surface discoloration on frozen bulk ground beef

	Freezing rate, hours to 0°F			
Evaluation time	24	48	72	96
Before freezing	4.88 ± .11bc	5.37 ± .09b	6.28 ± .13a	5.38 ± .12b
Immediately following freezing, 1 day	2.66 ± .12e	3.5 ± .12d	3.56 ± .12d	4.45 ± .12c

abcde Any mean comparison with different letters is different ($P<.05$); Mean ± S.E.

Table 35. Effect of freezing rate on sensory scores for surface discoloration on frozen bulk ground beef following various periods of storage — data adjusted for differences prior to freezing

Evaluation time	Freezing rate, hours to 0°F 24	48	72	96
Immediately following freezing, 1 day	3.25 ± .07bc	3.67 ± .07b	2.80 ± .07c	4.37 ± .07a
12 months	3.43 ± .18a	2.98 ± .18a	2.16 ± .18b	3.10 ± .18a

abc Means on the same line with different letters are different ($P<.05$). Mean ± S.E.

Table 36. Interaction effect of storage time (immediately following freezing, six months), initial storage temperature, final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day			2.65 ± .31abcde	3.56 ± .31abcd	3.61 ± .31abcd	4.27 ± .31a
6 months	-10	-10	2.90 ± .31abcde	3.97 ± .31ab	3.87 ± .31abc	3.75 ± .31abc
		0	3.05 ± .31abcd	3.15 ± .31abcd	3.42 ± .31abcd	3.62 ± .31abcd
		20	3.17 ± .31abcd	1.9 ± .31de	1.08 ± .31e	2.25 ± .31bcde
	0	-10	2.97 ± .31abcd	3.7 ± .31abcd	4.37 ± .31a	3.5 ± .31abcd
		0	3.32 ± .31abcd	3.45 ± .31abcd	3.71 ± .31abcd	2.87 ± .31abcde
		20	2.90 ± .31abcde	2.7 ± .31abcde	1.08 ± .31e	2.12 ± .31cde

abcde Any mean comparison with the same letters is not different ($P>.05$); Mean ± S.E.

Table 37. Interaction effect of storage time (immediately following freezing, six months), initial and final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef -- data adjusted for differences prior to freezing

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day			3.25 ± .31abcd	3.67 ± .31abcd	2.80 ± .31abcd	4.37 ± .31a
6 months	-10	-10	3.50 ± .31abcd	4.08 ± .31ab	3.07 ± .31abcd	3.85 ± .31abcd
		0	3.65 ± .31abcd	3.25 ± .31abcd	2.61 ± .31abcd	3.72 ± .31abcd
		20	3.77 ± .31abcd	2.00 ± .31de	0.28 ± .31e	2.35 ± .31bcd
	0	-10	3.57 ± .31abcd	3.80 ± .31abcd	3.57 ± .31abcd	3.60 ± .31abcd
		0	3.92 ± .31abc	3.55 ± .31abcd	2.91 ± .31abcd	2.97 ± .31abcd
		20	3.50 ± .31abcd	2.80 ± .31abcd	0.28 ± .31e	2.22 ± .31cd

abcde Any mean comparison with different letters is different ($P<.05$). Mean ± S.E.

Table 38. Interaction effect of storage time (immediately following freezing, nine months), initial storage temperature, final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day			2.65 ± .17defghi	3.56 ± .17abcdef	3.61 ± .17abcdef	4.27 ± .17abc
9 months	-10	-10T	1.91 ± .26ghijk	3.71 ± .17abcdef	3.85 ± .17abcd	2.39 ± .30fghi
		0T	2.42 ± .26efghij	3.25 ± .17abcdefg	2.93 ± .17cdefghi	2.64 ± .30defg
		20T	4.33 ± .26ab	2.21 ± .17ghijk	1.08 ± .17jk	2.52 ± .30defg
		20N	3.76 ± .26abcde	2.09 ± .17ghijk	1.00 ± .17k	0.89 ± .30k
	0	-10T	1.91 ± .26ghijk	3.21 ± .17bcdefgh	2.86 ± .17defghi	2.14 ± .30ghij
		0T	1.91 ± .26ghijk	2.62 ± .17defghi	2.87 ± .17defghi	2.14 ± .30ghij
		20T	4.58 ± .17a	1.79 ± .17ijk	1.10 ± .17jk	1.14 ± .30jk
		20N	3.76 ± .26abcde	2.09 ± .25ghijk	.89 ± .25k	1.89 ± .30hijk

abcdefghijk Any mean comparisons with different letters are different ($P<.05$); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

Table 39. Interaction effect of storage time (immediately following freezing, nine months), initial and final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef -- data adjusted for differences prior to freezing

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F: 24	48	72	96
Immediately following, freezing, 1 day			3.25 ± .17cdefg	3.67 ± .17bcd	2.80 ± .17defg	4.37 ± .17abc
9 months	-10	-10	2.51 ± .26defgh	3.81 ± .17bcd	3.05 ± .17cdefg	2.49 ± .30defgh
		0	3.02 ± .17cdefg	3.35 ± .17cde	2.13 ± .17efghi	2.74 ± .30defg
		20T	4.93 ± .17ab	2.31 ± .17efghi	.28 ± .17j	2.62 ± .30defg
		20N	4.36 ± .26abc	2.20 ± .25efghi	.20 ± .17j	.99 ± .30ij
	0	-10	2.51 ± .26defgh	3.31 ± .17cdef	2.06 ± .17efghi	2.24 ± .30efghi
		0	2.51 ± .26defgh	2.73 ± .17defg	2.07 ± .17efghi	2.24 ± .30efghi
		20T	5.18 ± .17a	1.90 ± .17ghi	.30 ± .17j	1.24 ± .30hij
		20N	4.36 ± .26abc	2.20 ± .25efghi	.092 ± .25j	1.99 ± .30fghi

abcdefghij Any mean comparison with different letters is different (P<.05).
Mean ± S.E. T = temperature abused, N = not temperature abused.

Table 40. Interaction effect of storage time (six, nine months) final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef

Evaluation time, months	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
6	-10	2.94 ± .23bcdef	3.84 ± .23ab	4.12 ± .23ab	3.62 ± .23abc
	0	3.19 ± .23abcdef	3.3 ± .23abcde	3.56 ± .23abc	3.25 ± .23abcdef
	20	3.04 ± .23abcdef	2.3 ± .23cdefg	1.08 ± .23g	2.19 ± .23cdefg
9	-10	1.94 ± .40efg	3.46 ± .23abcd	3.35 ± .23abcde	1.75 ± .40fg
	0	2.17 ± .33cdefg	2.94 ± .23bcdef	2.90 ± .23bcdef	2.00 ± .40defg
	20	4.46 ± .23a	2.0 ± .23defg	1.09 ± .23g	1.87 ± .40efg

abcdefg Any mean comparisons with the same letters are not different (P>.05); Mean ± S.E.

were not different for +20°F vs 0 and -10°F at 6 months, but less discoloration was found for +20°F stored product at nine months. Adjusting these data for pre-freezing differences did not appreciably alter the interpretation of this interaction (Table 41).

Following twelve months storage, the +20°F temperature still possessed an advantage in terms of less discoloration on product surface when freezing occurred to 0°F in 24 hours, although not in all the comparisons reported at nine months (Table 42). Across all freezing rates, only product initially and finally stored at 0°F had more discoloration than what was observed immediately following freezing (Table 43), when evaluations were taken at twelve months storage. In a freezing rate-time (nine, twelve months) interaction (+20°F final storage temperature removed) product frozen to 0°F in 24 months had more discoloration than other rates after nine months of storage, but was no different from other freezing rates after twelve months of storage (Table 44). Adjusting the data for pre-freezing differences in discoloration resulted in product subjected to the 0°F in 72 hour rate to be more discolored after both nine and twelve months than some of the other rates (Table 45). In an evaluation of storage time (nine, twelve months) final storage temperature and initial storage temperature, there were many inconsistent differences between initial-final storage temperature combinations, although none were significant ($P<.05$) by HSD tests (Table 46).

The next series of tables depicts surface discoloration values on thawed bulk ground beef. Advancements in storage time and the use of +20°F storage temperature produced the greatest increase in surface discoloration (Table 47). The main cause for the final storage temperature-freezing rate

Table 41. Interaction effect of storage time (six, nine months), final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef -- data adjusted for differences prior to freezing

Evaluation time, months	Final storage temperature, °F	Freezing rates, hours to 0°F			
		24	48	72	96
6	-10	3.54 ± .23bcd	3.94 ± .23ab	3.32 ± .23bcdef	3.72 ± .23abc
	0	3.79 ± .23abc	3.40 ± .23bcde	2.76 ± .23bcdef	3.35 ± .23bcdef
	20	3.64 ± .23abc	2.40 ± .23cdef	.28 ± .23g	2.29 ± .23cdef
9	-10	2.54 ± .40bcdef	3.56 ± .23abcd	2.55 ± .23bcdef	1.85 ± .40f
	0	2.77 ± .33bcdef	3.04 ± .23bcdef	2.10 ± .23def	2.10 ± .40def
	20	5.06 ± .23a	2.10 ± .23def	.29 ± .23g	1.97 ± .40ef

abcdefg Any mean comparison with different letters is different ($P<.05$). Mean ± S.E.

1103Q, p. 10

Table 42. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, final storage temperature and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef

			Freezing rate, hours to 0°F	
Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	24	48
Immediately following freezing, 1 day			2.65 ± .33bcd	3.56 ± .33abc
12 months	-10	-10T	2.10 ± .33d	2.96 ± .33bcd
		0T	3.22 ± .33abcd	3.08 ± .33bcd
		20N	4.45 ± .33a	2.29 ± .33cd
	0	-10T	3.70 ± .33ab	2.92 ± .33bcd
		0T	2.30 ± .33cd	2.54 ± .33bcd
		20N	4.55 ± .33a	2.75 ± .33bcd

abcd Any mean comparisons with the same letters are not different (P>.05); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

Table 43. Effect of storage time (immediately following freezing, twelve months) on sensory scores for surface discoloration on frozen bulk ground beef

Immediately following freezing, 1 day		12 months storage			
	Initial Storage temperature, °F =	-10		0	
	Final Storage temperature, °F =	-10	0	-10	0
3.52 ± .16a		2.89 ± .16ab	3.28 ± .16a	3.07 ± .16ab	2.42 ± .16b

ab Means on the same line with the same letters are not different (P>.05); Mean ± S.E.; Includes only temperature abused product.

Table 44. Interaction effect of storage time (nine, twelve months) and rate of freezing on sensory scores for surface discoloration on frozen bulk ground beef

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	1.98 ± .24b	3.20 ± .15a	3.13 ± .15a	2.52 ± .26ab
12	2.83 ± .15ab	2.87 ± .15ab	2.96 ± .15a	3.0 ± .15a

ab Any mean comparisons with the same letters are not different (P>.05); Mean ± S.E.

Table 45. Interaction effect of storage time (nine, twelve months) and freezing rate on sensory scores for surface discoloration on frozen bulk ground beef -- data adjusted for differences prior to freezing

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	2.58 ± .24abc	3.30 ± .15a	2.32 ± .15bc	2.62 ± .26abc
12	3.43 ± .15a	2.98 ± .15abc	2.16 ± .15c	3.10 ± .15ab

abc Any mean comparison with different letters is different ($P<.05$). Mean ± S.E.

Table 46. Interaction effect of storage time (nine, twelve months), final storage temperature and initial storage temperature on sensory scores for surface discoloration on frozen bulk ground beef[a]

Evaluation time, months	Final storage temperature, °F	Initial storage temperature, °F -10	Initial storage temperature, °F 0
9	-10	3.06 ± .21	2.42 ± .21
	0	2.84 ± .19	2.50 ± .21
12	-10	2.89 ± .15	3.07 ± .15
	0	3.28 ± .15	2.42 ± .15

[a]Interaction significant (P<.05) by Analysis of Variance, but not by HSD. Mean ± S.E.

Table 47. General table illustrating sensory scores for surface discoloration in thawed bulk ground beef throughout storage and according to final storage temperature and rate of freezing - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		4.88 ± .48	5.37 ± .55	6.28 ± .46	5.38 ± .53
Immediately following freezing, 1 day		3.92 ± .51	4.50 ± .76	3.77 ± 1.21	5.33 ± .65
6 months	-10T	2.77 ± .67	3.17 ± .90	3.65 ± .49	4.27 ± .81
	0T	2.85 ± .88	3.35 ± .96	3.62 ± .79	3.18 ± .59
	20T	1.75 ± .46	2.10 ± .66	1.51 ± .51	2.03 ± .62
9 months	-10T	2.26 ± .57	3.12 ± .51	2.33 ± .49	3.12 ± .92
	0T	2.42 ± .73	2.81 ± .55	2.18 ± .61	2.54 ± .76
	20T	1.35 ± .51	1.32 ± .48	1.00 ± .00	1.17 ± .43
	20N	.90 ± .39	1.42 ± .48	1.05 ± .17	.95 ± .48
12 months	-10T	2.54 ± .51	3.34 ± .48	2.70 ± .47	2.69 ± .60
	0T	2.21 ± .56	2.74 ± .57	2.55 ± .51	2.87 ± .50
	20N	1.06 ± .24	1.44 ± .51	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

interaction following six months storage, was whether +20°F stored product had more discoloration than the other rates (Table 48). For 0°F in 72 hour frozen product, there was more discoloration associated with +20°F storage, while for 0°F in 24 hour frozen product, there were no differences between freezing rates. Also, at six months, bulk ground beef stored at -10°F initial storage temperature had less discoloration than 0°F initial storage temperature product (Table 49).

After nine months of storage, bulk ground beef stored finally at -10 and 0°F had less surface discoloration than product stored at +20°F (Table 50). Somewhat surprisingly, bulk ground beef frozen to 0°F in 48 hours had less discoloration on thawed surfaces than bulk ground beef frozen to 0°F in 24 hours (Table 51). The colder initial storage temperature (-10°F) produced less surface discoloration following twelve months (Table 52).

Bulk ground beef at twelve months of storage that was frozen to 0°F in 24 hours possessed more surface discoloration than product frozen to 0°F in 48 hours regardless of whether the initial storage temperature was -10 or 0°F (Table 53). More discoloration on 0°F in 24 hour product was also noted at nine months. Within the 0°F in 24 hour freezing rate, -10°F initial storage temperature produced less surface discoloration on thawed surfaces. Warmer final storage temperatures produced more discoloration on thawed surfaces at twelve months (Table 54), regardless of initial storage temperature. More discoloration was found on 0°F vs -10°F initial storage temperatures, but not when the final storage temperature was +20°F.

Comparisons of surface discoloration scores following some period of storage with those obtained right after freezing showed more discoloration with storage as would be expected (Table 55). Freezing in itself produced

Table 48. Interaction effect of final storage temperature and rate of freezing on sensory scores for surface discoloration on thawed bulk ground beef following six months of storage

	Freezing rate, hours to 0°F			
Final Storage Temperature, °F	24	48	72	96
-10	2.77 ± .23bcd	3.17 ± .23abc	3.65 ± .23ab	4.27 ± .23a
0	2.85 ± .23bcd	3.35 ± .23ab	3.62 ± .23ab	3.18 ± .23abc
+20	1.75 ± .23de	2.10 ± .23cde	1.51 ± .23e	2.03 ± .23cde

abcde Any mean comparisons with different letters are different ($P < .05$).
Mean ± S.E.

Table 49. Effect of initial storage temperature on sensory scores for surface discolorations on thawed bulk ground beef following six months of storage

Initial Storage Temperature, °F	
-10	0
3.03 ± .09a	2.68 ± .09b

ab Differences between means are significant ($P < .05$). Mean ± S.E.

Table 50. Effect of final storage temperature on sensory scores for surface discoloration on thawed bulk ground beef following nine months storage

Final Storage Temperature, °F			
-10T	0T	+20T	+20N
2.72 ± 0.074a	2.49 ± 0.074a	1.21 ± 0.074b	1.10 ± 0.10b

ab Means on the same line with different letters are different ($P < .05$). Mean ± S.E. T = temperature abused, N = not temperature abused.

Table 51 . Effect of freezing rate on sensory scores for surface discoloration on thawed bulk ground beef following twelve months storage

Freezing rate, hours to 0°F			
24	48	72	96
2.37 ± .10b	3.04 ± .10a	2.62 ± .10ab	2.78 ± .10ab

ab Means on the same line with the same letter are not different ($P>.05$); Mean ± S.E.

Table 52. Effect of initial storage temperature on sensory scores for surface discoloration on thawed bulk ground beef following twelve months storage

Initial storage temperature, °F	
-10	0
2.84 ± .074a	2.57 ± .074b

ab Difference between means significant ($P<.05$); Mean ± S.E.

Table 53. Interaction effect of initial storage temperature and rate of freezing on sensory scores for surface discoloration on thawed bulk ground beef following twelve months storage

Initial storage temperature, °F	Freezing rate, hours to 0°F	
	24	48
-10	2.18 ± .069b	2.58 ± .069a
0	1.69 ± .069c	2.42 ± .069ab

ab Any mean comparisons with the same letters are not different (P>.05); Mean ± S.E.; Includes temperature and non-temperature abused product.

Table 54. Interaction effect of final storage temperature and initial storage temperature on sensory scores for surface discoloration on thawed bulk ground beef following twelve months storage

Final storage temperature, 0°F	Initial storage temperature, °F	
	-10	0
-10T	3.16 ± .084a	2.71 ± .084b
0T	2.74 ± .084b	2.21 ± .084c
20N	1.25 ± .084d	1.25 ± .084d

abcd Any mean comparison with a different letter is different (P<.05); Mean ± S.E.; Includes only 0°F in 24 and 48 hr freezing rates.

Table 55. Effect of various storage time comparisons on sensory scores for surface discoloration on thawed bulk ground beef

Evaluation times	
Immediately following freezing, 1 day	6 months
4.38 ± .17a	2.85 ± .17b
Immediately following freezing, 1 day	9 months
4.38 ± .15a	1.88 ± .15b
Immediately following freezing, 1 day[c]	12 months[c]
4.21 ± .10a	2.22 ± .10b
Immediately following freezing, 1 day[d]	12 months[d]
4.38 ± .11a	2.70 ± .11b
6 months	9 months
2.85 ± .081a	2.14 ± .081b

ab Differences between means on the same line are significant ($P<.05$); Mean ± S.E.

[c]Includes just 0°F in 24 and 48 hr freezing rates.

[d]Includes just temperature abused product.

more discoloration once product was thawed for all rates except 0°F in 96 hours (Table 56). Following freezing, the thawed surfaces of 0°F in 96 hour product were less discolored than 0°F in 24 and 72 hours. After six months of storage, increases in discoloration over that observed right after freezing, generally occurred only for bulk product stored at +20°F (Table 57). At twelve months, differences between just after freezing and various initial-final storage temperature combinations were most definitely freezing rate dependent, with the biggest decreases occurring for 0°F in 96 hour frozen product (Table 58).

The next set of tables relates to scores assigned for the amount of surface showing frost or ice crystals. This frost would be produced by moisture loss during freezing, temperature abuse and/or storage which would crystalize either on the surface of the bulk product or inside of the bag. Since it would only be visually detectable where there was a lack of adhesion between bag and product surface, the presence of frost may be due more to factors not under the control of the project design. The general table indicates an absence of real trends for percent frost (Table 59).

An interaction of storage time (six, nine months), final storage temperature and freezing rate was observed for percent frost, but no differences were significant via HSD (Table 60). After twelve months storage, +20°F final storage temperature generated less percent frost than the other two final storage temperatures (Table 61). The +20°F stored product at twelve months was possessing less frost than +20°F product at nine months and the other two rates at twelve months (Table 62). Compared to immediately following freezing, none of the initial-final storage temperature treatments at twelve months had less frost (Table 63). An

Table 56. Interaction effect of storage time (immediately before and after freezing) and rate of freezing on sensory scores for surface discoloration on thawed bulk ground beef

	Freezing rate, hours to 0°F			
Evaluation time	24	48	72	96
Before freezing	4.88 ± .11bcd	5.37 ± .09bc	6.28 ± .13a	5.38 ± .12b
Immediately following freezing, 1 day	3.92 ± .26e	4.5 ± .26cde	4.05 ± .21de	5.33 ± .26bc

abcde Any mean comparison with different letters is different ($P<.05$); Mean ± S.E.

Table 57. Interaction of initial storage temperature, final storage temperature, evaluation time and rate of freezing on sensory scores for surface discoloration of thawed bulk ground beef.

Initial storage temperatures °F	Final storage temperature °F	Evaluation time	Freezing rate, 0°F in hrs			
			24	48	72	96
		After freezing-one day	3.92 $\pm$ 0.31abcde	4.50 $\pm$ 0.31ab	3.77 $\pm$ 0.31abcdef	5.33 $\pm$ 0.31a
-10	-10	6 months	2.82 $\pm$ 0.31bcdefghi	3.35 $\pm$ 0.31bcdefgh	3.83 $\pm$ 0.31abcde	4.27 $\pm$ 0.31abc
	0	6 months	3.30 $\pm$ 0.31bcdefgh	3.75 $\pm$ 0.31abcdef	4.17 $\pm$ 0.31abcd	2.98 $\pm$ 0.31bcdefghi
	+20	6 months	1.60 $\pm$ 0.31hi	2.50 $\pm$ 0.31cdefghi	1.65 $\pm$ 0.31ghi	2.12 $\pm$ 0.31efghi
0	-10	6 months	2.72 $\pm$ 0.31bcdefghi	3.00 $\pm$ 0.31bcdefghi	3.46 $\pm$ 0.31bcdefg	4.27 $\pm$ 0.31abc
	0	6 months	2.40 $\pm$ 0.31defghi	2.95 $\pm$ 0.31bcdefghi	3.07 $\pm$ 0.31bcdefghi	3.38 $\pm$ 0.31bcdefgh
	+20	6 months	1.90 $\pm$ 0.31ghi	1.70 $\pm$ 0.31ghi	1.37 $\pm$ 0.31i	1.95 $\pm$ 0.31fghi

abcdefghi Any mean comparisons with different letters are different ($P < .05$) Mean $\pm$ S.E.

Table 58. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, final storage temperature and rate of freezing on sensory scores for surface discoloration on thawed bulk ground beef

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
Immediately following freezing, 1 day			3.92 ± .20bc	4.5 ± .20ab	3.77 ± .20bcd	5.33 ± .20a
12 months	-10	-10	2.87 ± .20cdef	3.45 ± .20bcd	2.4 ± .20ef	2.75 ± .20cdef
		0	2.55 ± .20def	2.92 ± .20cdef	2.8 ± .20cdef	3.0 ± .20cdef
	0	-10	2.2 ± .20 ef	3.22 ± .20cde	3.0 ± .20cdef	2.62 ± .20def
		0	1.87 ± .20f	2.55 ± .20def	2.3 ± .20ef	2.75 ± .20cdef

abcdef Any mean comparison with different letters is different ($P<.05$); Mean ± S.E.

Table 59. General table illustrating sensory scores for percent frost on bulk ground beef throughout storage and according to final storage temperature and rate of freezing - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F: 24	48	72	96
Immediately following freezing, 1 day		4.59 ± .74	3.94 ± .64	3.67 ± .48	4.45 ± .70
6 months	-10T	3.75 ± .73	4.11 ± .47	3.60 ± .51	4.12 ± .62
	0T	4.30 ± .57	3.50 ± .51	3.92 ± .69	3.62 ± .62
	20T	3.64 ± .50	4.55 ± .78	3.48 ± .69	4.12 ± .72
9 months	-10T	3.46 ± .52	4.08 ± .51	3.76 ± .84	4.17 ± .74
	0T	4.06 ± .32	4.23 ± .77	3.81 ± .69	3.67 ± .35
	20T	4.17 ± .53	4.33 ± .56	4.62 ± 1.22	3.54 ± .46
	20N	4.71 ± .55	3.71 ± .55	3.39 ± .65	3.29 ± .55
12 months	-10T	3.84 ± .50	3.79 ± .52	3.75 ± .45	3.75 ± .62
	0T	4.05 ± .70	3.87 ± .69	3.83 ± .39	4.17 ± .72
	20N	4.54 ± .71	5.10 ± .72	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 60. Interaction of final storage temperature, storage time (six, nine months) and rate of freezing on sensory scores for freezer burn in bulk ground beef[a]

Final Storage Temperature °F	Evaluation Time, months °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	6	3.75 ± .21	4.11 ± .21	3.60 ± .21	4.12 ± .21
-10	9	3.42 ± .36	4.08 ± .21	3.76 ± .21	4.25 ± .36
0	6	4.30 ± .20	3.50 ± .21	3.92 ± .21	3.62 ± .21
0	9	4.24 ± .29	4.23 ± .21	3.81 ± .21	4.00 ± .36
+20	6	3.64 ± .21	4.55 ± .21	3.48 ± .21	4.12 ± .21
+20	9	4.17 ± .20	4.33 ± .21	4.62 ± .21	3.50 ± .36

[a]Differences significant ($P<.05$) by analysis of variance, but not HSD.
Mean ± S.E.

Table 61. Effect of final storage temperature on sensory scores for percent frost on bulk ground beef following twelve months storage

Final storage temperature, °F		
-10T	0T	20N
3.81 ± .13b	3.96 ± .13b	4.82 ± .13a

ab Means on the same line with different letters are different ($P<.05$);
Mean ± S.E.; T = Temperature abused;
N = Not temperature abused.

Table 62. Interaction effect of storage time (nine, twelve months) and final storage temperature on sensory scores for percent frost on bulk ground beef

Evaluation time, months	Final storage temperature, °F		
	-10T	0T	20N
9	3.91 ± .16b	4.32 ± .14ab	3.86 ± .20b
12	3.81 ± .12b	3.96 ± .12b	4.82 ± .12a

ab Any mean comparison with the same letters is not different (P>.05); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

Table 63. Effect of storage time (immediately following freezing, twelve months) on sensory scores for percent frost on bulk ground beef

Immediately following freezing, 1 day		12 months storage					
	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
4.27 $\pm$ .18abc		3.90 $\pm$ .18bc	4.14 $\pm$ .18abc	4.70 $\pm$ .18ab	3.73 $\pm$ .18c	3.79 $\pm$ .18c	4.94 $\pm$ .18a

ab Any means on the same line with different letters are different ($P<.05$); Mean $\pm$ S.E. T = Temperature abused; N = Not temperature abused.

interaction was detected for time (nine, twelve months), initial and final temperatures and freezing rate although no differences were significant by HSD (Table 64).

General overall data for off-odor is presented in Table 65. In a general fashion, off-odor increased with storage time and the use of warmer storage temperatures (especially +20°F final storage temperature). Even after six months storage, +20°F final storage temperature generated more off-odor than -10 and 0°F (Table 66). This situation also occurred following nine and twelve months of storage (Table 67, 68) and at twelve months of storage, product stored at -10°F initial storage temperature had less off-odor than product stored at 0°F initial storage temperature (Table 69). The use of -10°F final storage temperature also produced less off-odor than 0°F final storage temperature (Table 70). This has been one of the few measured variables where some distinct differences have been found between -10°F and 0°F.

Advancements in storage time usually produced more detectable off-odor, although product stored nine months was scored as having less off-odor than product stored six months (Table 71). Freezing in itself generated some off-odor, especially for the 0°F in 24 and 48 hour rates. These two rates also were rated as having more off-odor immediatley following freezing than the other two rates (Table 72). After both six and twelve mohths of storage, the use of +20°F storage temperature produced more off-odor than what was noted immediately following freezing. This was true also for 0°F final storage temperature but only if the initial storage temperature was also 0°F (Table 73). The +20°F temperature produced more off-odor at twelve months compared to this same temperature after nine months of storage (Table 74). Whereas at nine months, off-odor scores did

Table 64. Interaction of initial storage temperature, final storage temperature, storage time (nine, twelve months) and rate of freezing on sensory scores for percent frost in bulk ground beef[a]

Initial Storage Temperature °F	Final Storage Temperature °F	Evaluation Time, months	Freezing rate, hours to 0°F			
			24	48	72	96
-10	-10	9	3.67 ± .36	3.96 ± .21	3.97 ± .21	3.50 ± .36
-10	-10	12	3.80 ± .21	4.00 ± .21	3.50 ± .21	3.50 ± .21
-10	0	9	4.00 ± .21	4.33 ± .21	3.92 ± .21	4.50 ± .36
-10	0	12	4.40 ± .21	3.87 ± .21	3.67 ± .21	3.83 ± .21
0	-10	9	3.79 ± .36	4.21 ± .21	3.55 ± .21	5.08 ± .36
0	-10	12	3.87 ± .21	3.58 ± .21	4.00 ± .21	4.00 ± .21
0	0	9	4.83 ± .36	4.12 ± .21	3.71 ± .21	3.92 ± .36
0	0	12	3.70 ± .21	3.87 ± .21	4.00 ± .21	4.50 ± .21

[a]Differences significant ($P < .05$) by analyses of variance, but not HSD. Mean ± S.E. Only -10 and 0°F rates of freezing represented.

Table 65. General table illustrating sensory scores for off-odor in thawed bulk ground beef throughout storage and according to final storage temperature and rate of freezing - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F: 24	48	72	96
Before freezing		4.00 ± .00	4.00 ± .00	4.00 ± .00	4.00 ± .00
Immediately following freezing, 1 day		3.58 ± .51	3.62 ± .52	4.00 ± .00	3.92 ± .29
6 months	-10T	3.02 ± .59	3.30 ± .46	3.64 ± .49	3.42 ± .50
	0T	3.07 ± .42	3.24 ± .55	3.63 ± .49	3.13 ± .35
	20T	2.60 ± .62	2.99 ± .66	2.63 ± .49	2.42 ± .50
9 months	-10T	2.50 ± .51	3.10 ± .54	2.56 ± .53	2.82 ± .51
	0T	2.39 ± .66	2.65 ± .46	2.69 ± .58	2.60 ± .62
	20T	1.45 ± .62	2.05 ± .77	1.56 ± .72	1.79 ± .73
	20N	1.76 ± .58	2.12 ± .76	2.47 ± .55	1.80 ± .29
12 months	-10T	2.95 ± .43	3.17 ± .51	2.80 ± .52	3.06 ± .44
	0T	2.51 ± .51	2.94 ± .54	2.65 ± .49	2.87 ± .34
	20N	1.15 ± .38	1.31 ± .48	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 66. Effect of final storage temperature on sensory scores for off-odor in bulk ground beef following six months of storage

Final Storage Temperature, °F		
-10	0	+20
3.35a	3.27a	2.66b

ab Means on the same line with the same letter are not different ($P > .05$). Mean $\pm$ S.E.

Table 67. Effect of final storage temperature on sensory scores for off-odor in thawed bulk ground beef following nine months storage

Final storage temperature, °F			
10T	0T	20T	20N
2.75 ± .093a	2.58 ± .093a	1.71 ± .093b	2.04 ± .13b

ab Means on the same line with different letters are different ($P<.05$); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

Table 68. Effect of final storage temperature on sensory scores for off-odor in bulk ground beef following twelve months of storage

	Final Storage Temperature, °F		
Temperature Abuse	-10	0	+20
T	2.99 ± .09a	2.72 ± .08a	--
N	--	--	1.23 ± .08b

ab Any mean comparisons with the same letter are not different ($P > .05$).
Mean ± S.E.

Table 69. Effect of initial storage temperature on sensory scores for off-odor in thawed bulk ground beef following twelve months storage

Initial storage temperature, °F	
-10	0
2.45 ± .072a	2.22 ± .072b

ab Difference between means significant (P<.05); Mean ± S.E. Includes just 0°F in 24 and 48 hr and both temperature and non-temperature abused product.

Table 70. Effect of final storage temperature on sensory scores for off-odor in bulk ground beef following twelve months of storage

Final Storage Temperature, °F	
-10	0
3.00 $\pm$ .08a	2.74 $\pm$ .07b

ab Means on the same line with different letters are different ($P<.05$). Mean $\pm$ S.E. Only -10°F and 0°F final storage product evaluated.

Table 71. Effect of various storage time comparisons on sensory scores for off-odor on thawed bulk ground beef

Evaluation times	
Immediately following freezing, 1 day	6 months
3.78 ± .10a	3.09 ± .10b
Immediately following freezing, 1 day	9 months
3.78 ± .14a	2.28 ± .14b
6 months	9 months
3.09 ± .06a	2.35 ± .06b
9 months	12 months
2.66 ± .06b	2.87 ± .06a
Immediately following freezing, 1 day	12 months[c]
3.78 ± .11a	2.87 ± .11b
Immediately following freezing, 1 day[d]	12 months[d]
3.60 ± .14a	2.34 ± .14b

ab Means on the same line with different letters are different ($P<.05$); Mean ± S.E.

[c]Includes all freezing rates, but just temperature abused product.

[d]Includes just 0°F in 24 and 48 hr freezing rates and both temperature and non-temperature abused product.

Table 72. Interaction effect of storage time (immediately before and after freezing) and freezing rate on sensory scores for off-odor in thawed bulk ground beef

	Freezing rate, hours to 0°F			
Evaluation time	24	48	72	96
Before freezing	4.00 ± .02a	4.00 ± .02a	4.00 ± .03a	4.00 ± .03a
Immediately after freezing, 1 day	3.58 ± .06b	3.62 ± .06b	4.00 ± .05a	3.92 ± .06a

ab Any mean comparison with the same letter is not different (P>.05); Mean ± S.E.

Table 73. Effect of various storage time comparisons on sensory scores for off-odor in thawed bulk ground beef

Immediately following freezing, 1 day		6 months					
	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10	0	20	-10	0	20
3.78 ± .095a		3.32 ± .095b	3.42 ± .095ab	2.76 ± .095cd	3.37 ± .095ab	3.11 ± .095bc	2.56 ± .095d
		12 months					
3.60 ± .13a		3.11 ± .13a	3.00 ± .13ab	1.25 ± .13c	3.01 ± .13ab	2.45 ± .13b	1.21 ± .13c

ab Means on the same line with different letters are different ($P<.05$); Mean ± S.E. Includes just 0°F in 24 hr freezing rate and temperature abused product for 12 months storage.

Table 74. Interaction effect of storage time (nine, twelve months) and final storage temperature on sensory scores for off-odor on thawed bulk ground beef

Evaluation time, months	Final storage temperature, °F		
	-10T	0T	20N
9	2.80 ± .13ab	2.52 ± .13ab	2.25 ± .21b
12	3.06 ± .13a	2.72 ± .13ab	1.23 ± .13c

abc Any mean comparison with the same letters is not different (P>.05); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

not differ ($P>.05$) among the three final storage temperatures, the +20°F temperature produced a decided increase in off-odor compared to the other two temperatures at nine months.

The next set of data for discussion includes TBA values. Compared to other products, the degree of change in TBA values for bulk ground beef was much less, especially as related to storage time and temperature (Table 75). Immediately following freezing, product originally frozen to 0°F in 72 hours had smaller TBA values than product subjected to the 0°F in 24 hour freezing rate (Table 76). After nine months of storage, within bulk ground beef stored at +20°F, 0°F in 48 hours produced lower TBA values than 0°F in 24 hours (Table 77).

After twelve months of storage, the 0°F in 96 hour freezing rate created higher TBA values than the other rates if the final storage temperature was 0°F. If the final storage temperature was -10°F, then this was true, but not for the 0°F in 24 and 0°F in 96 hour comparison (Table 78). Including the +20°F temperature in this interaction (which meant dropping the 0°F in 72 and 96 hour rates), the 0°F in 48 hour rate produced lower TBA values than 0°F in 24 hour rate when both -10 and +20°F temperatures of storage were employed (Table 79). An interaction of initial and final storage temperatures was also noted after twelve months, but no differences were significant ($P<.05$) by HSD procedures (Table 80).

Freezing in itself produced a small but significant ($P<.05$) increase in TBA values, while values at six and twelve months were slightly lower than those found immediately post-freezing (Table 81). At six months this reduction really was just for bulk ground beef originally stored at -10°F and finally stored at +20°F (Table 82). At twelve months of storage, the

Table 75. General Table illustrating TBA values in bulk ground beef throughout storage times according to final storage temperature and rate of freezing - no statistical analysis[a]

Evaluation Time	Final Storage Temperature, °F	Freezing rate, Hours to 0°F: 24	48	72	96
Before freezing		1.68 ± .07	1.44 ± .15	1.27 ± .13	1.43 ± .14
After freezing					
1 Day		1.75 ± .11	1.42 ± .10	1.38 ± .12	1.72 ± .18
6 months	-10	1.64 ± .15	1.36 ± .13	1.49 ± .31	1.58 ± .16
	0	1.57 ± .11	1.34 ± .11	1.44 ± .31	1.61 ± .11
	+20	1.57 ± .21	1.28 ± .14	1.44 ± .19	1.49 ± .26
9 months	-10	1.58 ± .25	1.10 ± .09	1.23 ± .19	1.49 ± .19
	0	1.66 ± .23	1.05 ± .04	1.24 ± .19	1.54 ± .22
	+20T	1.79 ± .17	1.15 ± .15	1.61 ± .37	1.47 ± .36
	+20N	1.33 ± .50	1.21 ± .33	1.81 ± .46	1.53 ± .48
12 months	-10	1.62 ± .21	1.24 ± .22	1.29 ± .07	1.57 ± .13
	0	1.49 ± .10	1.32 ± .23	1.37 ± .20	1.69 ± .14
	+20N	1.58 ± .22	1.26 ± .18	—	—

[a] Means ± S.D. T=temperature abused, N=not temperature abused.

Table 76. Effect of freezing rate on TBA values in bulk ground beef immediately following freezing[a]

	Freezing rate, hours to 0°F			
	24	48	72	96
TBA value	1.75 ± .05a	1.42 ± .05ab	1.38 ±.05b	1.72 ± .05ab

[a] Means on the same line with same letter are not different ($P > .05$). Mean ± S.E.

Table 77. Interaction effect of final storage temperature and rate of freezing on TBA values in bulk ground beef following nine months of storage

Final Storage Temperature °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10T	1.57 ± 0.098abcd	1.1 ± 0.098cd	1.23 ± 0.098bcd	1.49 ± 0.098abcd
0T	1.66 ± 0.098abc	1.05 ± 0.098d	1.24 ± 0.098bcd	1.54 ± 0.098abcd
+20T	1.79 ± 0.098ab	1.15 ± 0.098cd	1.61 ± 0.098abcd	1.47 ± 0.098abcd
+20N	1.33 ± 0.15abcd	1.20 ± 0.098cd	1.81 ± 0.098a	1.53 ± 0.123abcd

abcd Any mean comparisons with the same letters are not different (P > .05). Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 78. Interaction of final storage temperature and rate of freezing on TBA values of bulk ground beef following twelve months of storage.

Final Storage Temperature, 0°F	Temperature Abuse	Freezing rate, to 0°F in hours: 24	48	72	96
-10	T	1.62 ± .34ab	1.24 ± .34d	1.29 ± .34d	1.57 ± .34ab
0	T	1.49 ± .34bc	1.32 ± .34cd	1.37 ± .34cd	1.69 ± .34a

abcd Any mean comparisons with the same letter are different ($P < .05$)

Mean ± S.E. T=Temperature abused.

Table 79. Interaction of final storage temperature and rate of freezing on TBA values of bulk ground beef following twelve months of storage.

		Freezing rate, hour to 0°F	
Final Storage Temperature, 0°F	Temperature Abuse	24	48
-10	T	1.62 ± .04a	1.24 ± .04c
0	T	1.49 ± .04ab	1.32 ± .04bc
+20	N	1.62 ± .04a	1.21 ± .04c

ab Any mean comparisons with the same letter are not different ($P > .05$)
Mean ± S.E. T=Temperative abused. N= Not temperative abused. 0°F in 72 and 96 hour frozen product had no +20°F stored produced at twelve months

Table 80. Interaction effect of final storage temperature and initial storage temperature on TBA values for bulk ground beef following twelve months of storage[a]

Final Storage Temperature, °F	Temperature Abuse	Initial Storage Temperature, °F	
		-10	0
-10	T	1.47 $\pm$ .02	1.39 $\pm$ .02
0	T	1.45 $\pm$ .02	1.48 $\pm$ .02

[a]Differences significant with analysis of variance, but not HSD. Mean $\pm$ S.E. Includes only temperature abused product.

Table 81. Effect of various storage time comparisons on TBA values for bulk ground beef

Evaluation times	
Immediately before freezing	Immediately after freezing, 1 day
1.46 ± .03b	1.57 ± .03a
Immediately after freezing, 1 day	6 months
1.57 ± .03a	1.48 ± .03b
Immediately after freezing, 1 day	12 months[c]
1.57 ± .03a	1.45 ± .03b
Immediately after freezing, 1 day	12 months[d]
1.58 ± .04a	1.41 ± .04b

ab Means on the same line with different letters are different ($P<.05$); Mean ± S.E.

[c]Includes just temperature abused product.

[d]Includes just 0°F in 24 and 48 hr freezing rate.

Table 82. Effect of various storage time comparisons on TBA values for bulk ground beef

Immediately following freezing, 1 day	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10	0	20	-10	0	20
		6 months storage					
1.57 ± .034a		1.51 ± .034ab	1.50 ± .034ab	1.39 ± .034b	1.52 ± .034ab	1.48 ± .034ab	1.50 ± .034[illegible]
		12 months[c]					
1.57 ± .026a		1.47 ± .026ab	1.45 ± .026b	--	1.39 ± .026b	1.48 ± .026ab	--
		12 months[d]					
1.58 ± .036a		1.47 ± .036ab	1.38 ± .036b	1.41 ± .036ab	1.39 ± .036b	1.42 ± .036ab	1.42 ± .036[illegible]

ab Means on the same line with the same letters are not different ($P>.05$); Mean ± S.E.

[c]Includes only temperature abused product.

[d]Includes just 0°F in 24 and 48 hr freezing rates.

decrease was basically for product originally stored at -10°F and finally at 0°F and product originally stored at 0°F and finally at -10°F.

An interaction of storage time (six, nine months) and freezing rate showed that the 0°F in 48 hour freezing rate produced lower TBA values, although at six months the values did not differ for those noted for the 0°F in 72 hours (Table 83). Six and nine months were also involved in an interaction for TBA with final storage temperature (Table 84), but no differences were detected by HSD ($P>.05$). A nine-twelve month interaction with freezing rate produced similar results to those found for six and nine months, except that at twelve months there were also no differences between 0°F in 48 and 72 hours (Table 85).

It would appear that product frozen to 0°F in 48 hours was able to withstand change in TBA as a result of storage slightly more than the other rates. However, it does not appear that changes in TBA (or really absence of) parallel those noted for off-odor and discoloration.

The following tables provide sensory panel responses for various detectable flavors obtained from the meat loaf made from the bulk ground beef. Immediately following freezing, differences were noted in the frequency of detected flavors; however, they don't appear to follow any trend related to freezing rate (Table 86). After six months of storage, salty appears to be a major flavor note, although no pattern of occurrence was obvious according to freezing rate-final storage temperature combinations (Table 87). Rancid appeared as a flavor primarily in product of all rates stored at +20°F. At nine months of storage, a significant ($P<.018$) difference between initial storage temperature was found, although the distribution of flavors overall was not greatly different between the two temperatures (Table 88).

Table 83. Interaction effect of storage time (six, nine months) and rate of freezing or TBA values in bulk ground beef

Evaluation time, mo	Freezing rate, hours to 0°F			
	24	48	72	96
6	1.59 ± .04ab	1.33 ± .04cd	1.45 ± .04abc	1.56 ± .04ab
9	1.67 ± .04a	1.10 ± .04d	1.36 ± .04bc	1.50 ± .04abc

[abcd]Any mean comparisons with different letters are not different (P < .05).
Mean ± S.E.

Table 84. Interaction of storage time (six, nine mos.) and final storage temperature on TBA values in bulk ground beef

Evaluation time, months	Final Storage Temperature °F		
	-10	0	+20
6	1.52 ± .04	1.49 ± .04	1.45 ± .04
9	1.35 ± .04	1.37 ± .04	1.51 ± .04

a Differences significant (P>.05). through analysis of variance, but not HSD.
Mean ± S.E.

Table 85. Interaction effect of storage time (nine, twelve months) and rate of freezing on TBA values for bulk ground beef

Evaluation time, mo	Freezing rate, hours to 0°F			
	24	48	72	96
9	1.62 ± 0.037a	1.08 ± 0.037c	1.24 ± 0.037bc	1.52 ± 0.037a
12	1.55 ± 0.037a	1.28 ± 0.037b	1.33 ± 0.037b	1.63 ± 0.037a

[abc]Any mean comparisons with the same letters are not different (P > .05)
Mean ± S.E. No +20°F stored product included.

Table 86. Detectable flavor scores assigned to meat loaf made from bulk ground beef according to freezing rate immediately following freezing[a]

Detectable flavor	Freezing rate, hours to 0°F			
	24	48	72	96
Sour	0.00	0.00	2.1	8.3
Bitter	8.3	0.00	0.00	0.00
Metallic	33.3	18.7	20.8	16.7
Sweet	0.00	6.2	4.2	16.7
Rancid	8.3	0.00	0.00	0.00
Salty	37.5	50.0	39.6	29.2
Unidentified	12.5	25.0	33.3	29.3

$X^2 = 30.24$, $P<.035$.

[a]Values are percentages of scores assigned within rate of freezing.

Table 87 . Detectable flavor scores assigned to meat loaf made from bulk ground beef according to freezing rate and final storage temperature following six months storage[a]

Freezing Rate, hrs to 0°F	Final Storage Temperature, 0°F	Detectable Flavor: Sour	Bitter	Metallic	Sweet	Rancid	Salty	Unidentified
24	-10	7.2	7.2	9.5	2.4	0.0	50.0	23.8
	0	0.0	5.3	15.8	2.6	7.9	50.0	18.4
	+20	2.3	4.6	15.9	6.8	13.6	31.8	25.0
48	-10	5.9	0.0	17.6	11.8	8.8	32.3	23.5
	0	5.1	5.1	17.9	2.6	15.4	43.6	10.3
	+20	4.0	10.0	2.0	2.0	16.0	46.0	20.0
72	-10	5.9	5.9	20.6	5.9	0.0	26.5	35.3
	0	0.0	2.6	18.4	5.3	0.0	50.0	23.7
	+20	3.1	0.0	9.4	6.2	15.6	40.6	25.0
96	-10	0.0	5.6	16.7	5.6	0.0	61.1	11.1
	0	0.0	11.6	2.3	2.3	9.3	46.5	27.9
	+20	2.2	2.2	17.4	0.0	17.4	37.0	23.9

$X^2 = 30.24$, $P<.047$.
[a]Values are percentages of scores assigned within a freezing rate - final storage temperature combination.

Table 88. Detectable flavor scores assigned to meat loaf made from bulk ground beef according to initial storage temperature following nine months storage[a]

Detectable flavor	Initial storage temperature, °F -10	0
Sour	6.4	7.3
Bitter	11.9	14.6
Metallic	12.9	12.0
Sweet	8.9	14.6
Rancid	15.8	21.9
Salty	22.8	15.6
Aged cheese	3.0	5.7
Unidentified	18.3	8.3

$\chi^2 = 16.97 \quad P<.018.$

[a]Values are percentages of scores assigned within an initial storage temperature.

The breakdown of various detectable flavors at nine months according to freezing rate-final storage temperature combinations does reveal some interesting distributions (Table 89). Obviously, the sole presence (32% of the flavors identified for this rate-temperature combination) of aged cheese flavor for meat loaf derived from the bulk ground beef frozen to 0°F in 24 hours and finally stored at +20°F is associated with the presence of off-odor (cheesy) in the thawed bulk product. This particular product also possessed the more red color following nine months storage. With the slower freezing rates, +20°F storage seemed to escalate the observance of rancid flavors. There was some tendency for bitter to be present in meat loaf made from +20°F stored product vs the other two temperatures.

After twelve months of storage, temperature abused product had more occurrence of salty flavors (Table 90). Again at twelve months, aged cheese flavor was found in meat loaf processed from bulk ground beef frozen to 0°F in 24 hours and then stored at +20°F (Table 91). Salty was observed in meat loaf less if it was processed from +20°F stored product. This was probably due to the higher frequency of rancid flavor for +20°F stored product. Metallic was observed more often at twelve months than nine months.

Table 92 illustrates the change in percent frequency of rancid flavor over storage and as affected by freezing rate and final storage temperature. With the exception of nine months for product frozen to 0°F in 24 hours (considerable cheese flavor then), +20°F storage resulted in a higher frequency of rancid flavor. Also, there were increases in occurrence between six and nine months, especially for product stored at +20°F. However, decreases in rancid flavor generally occurred between nine and twelve months.

Table 89. Detectable flavor scores assigned to meat loaf made from bulk ground beef according to freezing rate and final storage temperature following nine months storage[a]

		Detectable Flavor							
Freezing Rate hrs to 0°F	Final Storage Temperature, 0°F	Sour	Bitter	Metallic	Sweet	Rancid	Salty	Aged Cheese	Unidentified
24	-10	22.7	13.6	4.5	4.5	18.2	22.7	0.0	13.6
	0	4.2	0.0	12.5	16.7	8.3	33.3	0.0	25.0
	+20	11.3	22.6	11.3	1.9	5.7	13.2	32.1	1.9
48	-10	10.5	5.3	5.3	10.5	10.5	47.4	0.0	10.5
	0	0.0	0.0	15.0	40.0	20.0	10.0	0.0	15.0
	+20	6.2	10.4	14.6	14.6	20.8	20.8	0.0	12.5
72	-10	0.0	5.9	23.5	17.6	0.0	23.5	0.0	29.4
	0	0.0	9.1	9.1	18.2	13.6	31.8	0.0	18.2
	+20	6.7	15.0	13.3	8.3	30.0	15.0	0.0	11.7
96	-10	14.3	10.7	10.7	7.2	14.3	17.9	0.0	25.0
	0	0.0	25.0	12.5	16.7	8.3	12.5	0.0	25.0
	+20	3.5	17.5	14.0	8.8	38.6	12.3	0.0	5.3

Chi-square = 235.9, $P<.0001$.

[a]Values are percentages of scores assigned within a freezing rate - final storage temperature combination.

Table 90. Detectable flavor scores assigned to meat loaf made from bulk ground beef according to temperature abuse following twelve months storage[a]

	Temperature Abuse	
Detectable Flavor	T	N
Sour	14.1	8.9
Bitter	11.1	10.9
Metallic	21.2	25.6
Sweet	7.1	8.1
Rancid	13.1	3.7
Putrid	1.0	0.00
Salty	15.1	26.5
Aged cheese	9.1	0.00
Unidentified	8.1	16.1

Chi-square = 57.1, $P<.0001$.
[a]Values are percentages of scores assigned within temperature (T) or nontemperature abuse (N) categories.

Table 91. Detectable flavor scores assigned to meat loaf made from bulk ground beef according to freezing rate and final storage temperature following twelve months storage[a]

Freezing Rate, hrs to 0°F	Final Storage Temperature, 0°F	Detectable Flavors								
		Sour	Bitter	Metallic	Sweet	Rancid	Putrid	Salty	Aged Cheese	Unidentified
24	-10	15.9	4.5	22.7	11.4	6.8	0.0	22.7	0.0	15.9
	0	12.2	4.1	34.7	8.2	4.1	0.0	18.4	0.0	18.4
	+20	10.4	14.6	16.7	6.2	12.5	2.1	12.5	18.7	6.2
48	-10	6.0	2.0	20.0	8.0	4.0	0.0	44.0	0.0	16.0
	0	5.3	7.9	23.7	2.6	7.9	0.0	39.5	0.0	13.2
	+20	17.6	7.8	25.5	7.8	13.7	0.0	17.6	0.0	9.8
72	-10	9.3	18.5	31.5	9.3	3.7	0.0	22.2	0.0	5.5
	0	4.2	25.0	25.0	2.1	2.1	0.0	29.2	0.0	12.5
96	-10	2.9	20.0	22.9	8.6	0.0	0.0	17.1	0.0	28.6
	0	17.2	3.4	20.7	17.2	0.0	0.0	13.8	0.0	27.6

Chi-square = 180.51, $P<.0001$.

[a]Values are percentages of scores assigned within freezing rate - final storage temperature following twelve months storage.

Table 92 . Incidence of rancid flavor in meat loaf made from bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

		Evaluation Time				
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	0.00	8.33			
	-10			0.00	18.18	6.82
	0			7.89	8.33	4.08
	+20			13.64	5.66	12.50
48	--	4.55	0.00			
	-10			8.82	10.53	4.00
	0			15.38	20.00	7.89
	+20			16.00	20.83	13.73
72	--	0.00	0.00			
	-10			0.00	0.00	3.70
	0			0.00	13.64	2.08
	+20			15.63	30.00	--
96	--	2.44	0.00			
	-10			0.00	14.29	0.00
	0			9.30	8.33	0.00
	+20			17.39	38.60	--

[a]Values are percent occurrence of rancid flavor among all flavors within a storage time-freezing rate-final storage temperature combination.

As has been previously mentioned, the aged cheese flavor appeared strictly in one rate-temperature combination (0°F in 24 hours, +20°F storage) and is shown in Table 93. Sour flavor appeared sporadically, and followed no real trend (Table 94). Metallic as a flavor component underwent a reduction in meat loaf simply by freezing the bulk ground beef (Table 95). However, this note again became elevated following twelve months storage.

It would appear from these results for various detectable flavors that TBA didn't always relate to the presence of rancid flavor.

The next series of tables provides information on seasoning intensity and thus may not be strictly related to the variables inherent to the project design. The highest intensity of seasoning appeared in meat loaf processed from ground beef just before and after freezing (Table 96). This is not too surprising, since with storage, other flavors appeared and diluted the impact of seasoning. Likewise, +20°F storage following twelve months probably reduced seasoning flavor intensity due to the presence of other flavors (Table 97). Storage time comparisons with product immediately following freezing show a reduction with storage for seasoning intensity (Table 98). After nine months, meat loaf made from bulk ground beef stored initially at 0 and finally at +20°F had lower seasoning intensity than loaf manufactured immediately following freezing (Table 99). In comparing seasoning intensity between six and nine months according to final storage temperature, nine months produced a decrease in intensity from six months only for +20°F storage (Table 100). Following twelve months of storage, only product stored at +20°F produced lower seasoning intensity to that found after freezing in comparisons involving all combinations of initial and final storage temperature (Table 101).

Table 93. Incidence of aged cheese flavor in meat loaf made from bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time: Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	0.00	0.00			
	-10			0.00	0.00	0.00
	0			0.00	0.00	0.00
	+20			0.00	32.08	18.75
48	--	0.00	0.00			
	-10			0.00	0.00	0.00
	0			0.00	0.00	0.00
	+20			0.00	0.00	0.00
72	--	0.00	0.00			
	-10			0.00	0.00	0.00
	0			0.00	0.00	0.00
	+20			0.00	0.00	0.00
96	--	0.00	0.00			
	-10			0.00	0.00	0.00
	0			0.00	0.00	0.00
	+20			0.00	0.00	0.00

[a]Values are percent occurrence of aged cheese flavor among all flavors within a storage time-freezing rate-final storage temperature combination.

Table 94. Incidence of sour flavor in meat loaf made from bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time: Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	0.00	0.00			
	-10			7.14	22.73	15.91
	0			0.00	4.17	12.24
	+20			2.27	11.32	10.42
48	--	0.00	0.00			
	-10			5.88	10.53	6.00
	0			5.13	0.00	5.26
	+20			4.00	6.25	17.65
72	--	3.45	2.08			
	-10			5.86	0.00	9.26
	0			0.00	0.00	4.17
	+20			3.13	6.67	--
96	--	0.00	8.33			
	-10			0.00	14.29	2.86
	0			0.00	0.00	17.24
	+20			2.17	3.51	--

[a]Values are percent occurrence of sour flavor among all flavors within a storage time-freezing rate-final storage temperature combination.

Table 95. Incidence of metallic flavor in meat loaf made from bulk ground beef throughout storage and according to freezing rate and final storage temperature[a]

		Evaluation Time				
Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	44.44	33.00			
	-10			9.52	4.55	22.73
	0			15.79	12.50	34.69
	+20			15.91	11.32	16.67
48	--	40.91	18.75			
	-10			17.65	5.26	20.00
	0			17.95	15.00	23.68
	+20			2.00	14.58	25.49
72	--	48.28	20.83			
	-10			20.59	23.53	31.48
	0			18.42	9.09	25.00
	+20			9.38	13.33	--
96	--	21.95	16.67			
	-10			16.67	10.71	22.86
	0			2.33	12.50	20.69
	+20			17.39	14.04	--

[a]Values are percent occurrence of metallic flavor among all flavors within a storage time-freezing rate-final storage temperature combination.

Table 96. General table illustrating sensory scores for seasoning intensity in meat loaf from bulk ground beef throughout storage times according to final storage temperature and freezing rate - no statistical analyses

Evaluation Time, months	Final Storage Temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		4.27 ± .92	4.51 ± .76	4.59 ± .68	4.23 ± 1.02
After freezing 1 day		4.37 ± .90	4.33 ± .80	4.71 ± .87	4.32 ± 1.07
6 months	-10	3.23 ± .82	3.81 ± 1.00	3.75 ± .92	3.52 ± 1.02
	0	3.39 ± .90	3.63 ± .95	3.64 ± 1.03	3.41 ± 1.12
	+20 T	3.54 ± 1.01	3.32 ± .84	3.67 ± .92	3.37 ± 1.01
9 months	-10	3.34 ± .93	3.96 ± .97	3.81 ± 1.41	3.03 ± 1.15
	0	4.12 ± 1.31	3.71 ± .91	3.72 ± 1.12	3.44 ± 1.09
	+20 T	3.11 ± 1.13	3.07 ± 1.52	2.97 ± 1.47	2.91 ± .93
	+20 N	3.72 ± 1.20	3.78 ± .98	3.15 ± 1.35	3.00 ± .95
12 months	-10	3.53 ± 1.06	3.73 ± 1.18	3.37 ± 1.00	3.37 ± 1.07
	0 T	3.73 ± 1.05	3.69 ± .93	3.26 ± .91	3.99 ± 1.08
	+20 N	2.49 ± 1.09	3.12 ± .96	--	--

Mean ± S.D.

Table 97. Effect of final storage temperature on sensory scores for intensity of seasoning flavor in meat loaf made from bulk ground beef stored twelve months

	Final Storage Temperature, °F		
Temperature Abuse	-10	0	+20
Y	3.63 ± .16a	3.72 ± .16a	--
N	--	--	2.81 ± .16b

ab Any mean comparisons with different letters are different (P < .05). Mean ± S.E. Y = temperature abused, N = not temperature abused.

Table 98. Effect of various storage time comparisons on sensory scores for meat loaf seasoning intensity in meat loaf made from bulk ground beef

Evaluation time	
Immediately following freezing, 1 day	6 months
4.43 ± .084a	3.52 ± .084b
Immediately following freezing, 1 day	9 months
4.43 ± .14a	3.36 ± .14b
Immediately following freezing, 1 day	12 months[c]
4.35 ± .23a	3.39 ± .23b
Immediately following freezing, 1 day	12 months[d]
4.43 ± .11a	3.55 ± .11b

ab Means on the same line with different letters are different (P<.05).
Means ± S.E.
[c]Includes just temperature abused product.
[d]Includes just 0°F in 24 and 48 hr product.

Table 99. Effect of storage time (immediately following freezing, nine months) on sensory scores for meat loaf seasoning intensity in meat loaf made from bulk ground beef

Immediately following freezing, 1 day	Temperature abuse		9 Months Storage					
		Initial Storage temperature, °F =	-10			0		
		Final Storage temperature, °F =	-10	0	20	-10	0	20
4.43 ± .14a	T		3.64 ± .22a	3.61 ± .22a	3.18 ± .22ab	3.42 ± .22ab	3.77 ±.22a	2.64 ± .22b
	N		--	--	3.33 ± .20ab	--	--	3.30 ± .22ab

ab Any mean comparison with the same letter is not different (P>.05); Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 100. Interaction of storage time (six, nine mos) and final storage temperature on sensory scores for seasoning intensity in meat loaf made from bulk ground beef

Evaluation Time, months	Final Storage Temperature, °F		
	-10	0	+20
6	3.58 ± .07a	3.52 ± .07a	3.48 ± .07a
9	3.54 ± .10a	3.75 ± .10a	3.01 ± .10b

ab Any mean comparisons with the same letter are not different ($P > .05$). Mean ± S.E.

Table 101. Effect of storage time (immediately following freezing, twelve months) on sensory scores for meat loaf seasoning intensity in meat loaf made from bulk ground beef

				12 Months Storage			
	Initial Storage temperature, °F =	-10			0		
Immediately following freezing, 1 day	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
4.35 ± .21a		3.82 ± .21ab	3.67 ± .21ab	2.59 ± .21c	3.45 ± .21abc	3.75 ± .21ab	3.02 ± .21bc

abc Means on the same line with different letters are different ($P<.05$); mean ± S.E. T = temperature abused, N = not temperature abused.

General information pertaining to cereal flavor intensity is exhibited in Table 102. Like seasoning intensity, the highest intensity scores were observed either just before or after freezing. All the various storage periods produced declines in cereal flavor intensity when compared to immediately following freezing. This is obviously due to the appearance of other flavors (rancid) as storage progressed. However, meat loaf made from twelve month stored bulk ground beef had more cereal flavor intensity than meat loaf evaluated at nine months (Table 103). With the exception of 0°F initial and -10°F final storage temperatures, all other temperature combinations at twelve months produced reductions in cereal flavor intensity in resultant meat loaf compared to loaf made just after freezing (Table 104).

Values for sensory panel evaluations for softness in meat loaf are given next. In a general way (Table 105) values for softness were not greatly affected by project variables. In product made before freezing, the formulation selected for 0°F in 96 hours produced less softness in resultant meat loaf than the other three rates. This also occurred following nine months of storage, but not at six or twelve months (Table 106). After six months of storage, freezing rate and initial storage temperature were involved in a significant ($P<.05$) interaction (Table 107). This interaction was detected due to the 0°F in 24 hour freezing rate producing more softness in meat loaf than 0°F in 48 hours, but only for the 0°F initial storage temperature. At the completion of nine months storage (Table 108) for just bulk ground beef initially stored at 0°F, +20°F final storage temperature created higher scores for softness in meat loaf than -10°F. Table 109 indicates that a significant ($P<.05$) initial-final

Table 102. General table illustrating sensory scores for cereal flavor intensity in meat loaf made from bulk ground beef throughout storage and according to final storage temperature and rate of freezing - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		3.60 ± .98	3.54 ± 1.00	3.81 ± .83	3.23 ± .87
Immediately following freezing, 1 day		3.44 ± .84	3.57 ± .96	3.47 ± 1.02	3.44 ± .70
6 months	-10	2.32 ± .69	2.49 ± .70	2.63 ± .77	2.26 ± .89
	0	2.28 ± .65	2.57 ± .85	2.76 ± .73	2.22 ± .74
	20	2.20 ± .77	2.81 ± .83	2.50 ± .64	2.28 ± .67
9 months	-10	2.27 ± .77	2.62 ± .94	2.54 ± .93	2.49 ± 1.01
	0	2.16 ± .84	2.47 ± 1.03	2.45 ± .80	2.55 ± .99
	20 T	2.76 ± 1.40	2.62 ± 1.00	2.42 ± .97	2.14 ± .85
	20 N	2.70 ± .89	2.36 ± .77	2.25 ± 1.12	2.30 ± .85
12 months	-10	2.95 ± .72	2.80 ± .62	2.39 ± .53	2.73 ± .65
	0	2.91 ± .85	2.64 ± .76	2.72 ± .71	2.50 ± .57
	20 N	2.52 ± .97	2.61 ± .79	--	--

[a]Mean ± S.D.. T = temperature abused, N = not temperature abused.

Table 103. Effect of various storage time comparisons on intensity of cereal flavor in meat loaf made from bulk ground beef

Evaluation times	
Immediately following freezing, 1 day	6 months
3.48 ± .12a	2.44 ± .12b
Immediately following freezing, 1 day	9 months
3.48 ± .094a	2.47 ± .094b
Immediately following freezing, 1 day	12 months[c]
3.48 ± .08a	2.70 ± .08b
Immediately following freezing, 1 day	12 months[d]
3.51 ± .15a	2.74 ± .15b
9 months	12 months[d]
2.29 ± .12b	2.74 ± .07a
9 months	12 months[c]
2.40 ± .09b	2.70 ± .05a

ab Differences between means in the same line are different ($P<.05$)
[c]Includes just temperature abused product.
[d]Includes just 0°F in 24 and 48 hr freezing rates.

Table 104. Effect of storage time (immediately following freezing, twelve months) on sensory scores for cereal flavor intensity in meat loaf made from bulk ground beef

Immediately following freezing, 1 day		12 Months Storage					
	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
3.51 ± .14a		2.79 ± .14b	2.78 ± .14b	2.51 ± .14b	2.96 ± .14ab	2.76 ± .14b	2.62 ± .14b

ab Means on the same line with different letters are different (P<.05); Mean ± S.E. Includes just 0°F in 24 and 48 hr freezing rates. T = temperature abused, N = not temperature abused.

Table 105. General table illustrating sensory scores for softness in meat loaf throughout storage times and according to final storage temperature and freezing rate - no statistical analyses

		Freezing Rate, Hours to 0°F			
Evaluation Time	Final Storage Temperature, °F	24	48	72	96
Before freezing		4.77 ± .65	5.66 ± .71	5.66 ± .68	4.95 ± .72
After freezing 1 day		5.35 ± .68	5.25 ± .73	5.27 ± .65	4.96 ± .73
6 months	-10	5.55 ± 1.05	4.98 ± .95	5.37 ± .76	5.37 ± .92
	0	5.45 ± 1.05	5.31 ± 1.09	5.25 ± .96	5.43 ± .92
	+20 T	5.50 ± 1.06	5.42 ± 1.07	5.85 ± .76	5.48 ± .87
9 months	-10	5.65 ± .98	5.50 ± 1.26	5.57 ± 1.28	5.06 ± 1.17
	0	6.05 ± .78	5.75 ± 1.28	5.66 ± .88	5.09 ± 1.34
	+20 T	5.97 ± .55	6.36 ± .77	6.04 ± .86	4.96 ± .95
	+20 N	5.69 ± .62	5.73 ± .57	5.51 ± .61	4.99 ± 1.13
12 months	-10	4.68 ± .67	5.16 ± .74	5.41 ± .79	5.27 ± .70
	0	4.72 ± .63	4.90 ± .83	4.95 ± .81	5.03 ± .85
	+20 T	5.62 ± .55	5.00 ± .64	--	--

Mean ± S.D. T = temperature abuse, N = not temperature abuse.

Table 106. Effect of freezing rate on sensory scores for softness in meat loaf made from bulk ground beef following various storage periods

	Freezing rate, hours to 0°F			
Storage time	24	48	72	96
Immediately before freezing, 1 day	5.15 ± .11ab	5.56 ± .11a	5.66 ± .11a	4.92 ± .11b
9 months	5.84 ± .09a	5.83 ± .16a	5.69 ± .12a	5.02 ± .16b

ab Means on the same line with different letters are different ($P<.05$).
Mean + S.E.

Table 107. Interaction effect of initial storage temperature and freezing rate on sensory scores for softness in meat loaf made from bulk ground beef following six months storage

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	5.23 $\pm$ .13ab	5.33 $\pm$ .13ab	5.63 $\pm$ .13ab	5.43 $\pm$ .13ab
0	5.78 $\pm$ .13a	5.14 $\pm$ .13b	5.36 $\pm$ .13ab	5.43 $\pm$ .13ab

ab Any mean comparisons with the same letters are not different (P>.05).
Mean + S.E.

Table 108. Interaction of final storage temperature and initial storage temperature on sensory scores for softness in meat loaf following nine months storage of bulk ground beef

		Initial Storage Temperature, °F	
Final storage temperature, °F	Temperature abuse	-10	0
-10	Y	5.69 ± .12ab	5.20 ± .12b
0	Y	5.45 ± .12ab	5.81 ± .12ab
+20	Y	5.70 ± .12ab	5.92 ± .12a
+20	N	5.51 ± .12ab	5.44 ± .12ab

ab Any mean comparisons with the same letters are not different (P > .05)
Mean ± S.E.
Y = temperature abused, N = not temperature abused

Table 109. Interaction effect of initial storage temperature and final storage temperature on sensory scores for softness in meat loaf made from bulk ground beef stored twelve months[a]

Initial storage temperature, 0°F	Final storage temperature, °F	
	-10	0
-10	5.29 ± .13	4.97 ± .13
0	4.78 ± .13	5.01 ± .13

[a]Interaction significant ($P<.05$) by analysis of variance, but not by HSD. Mean ± S.E. Includes only temperature abused product.

temperature interaction was noted for meat loaf softness at twelve months, but no mean differences were significant (P>.05).

Nine months storage generated an increase in meat loaf softness compared to values found right after freezing, while the opposite was true for twelve months (Table 110). Nine months storage produced an increase over six months for meat loaf softness if bulk product was frozen to 0°F in 48 hours; the opposite occurred for product frozen to 0°F in 96 hours (Table 111). At nine months the three faster rates produced higher softness scores than the 0°F in 96 hour rate. Between nine and twelve months, nine months storage resulted in higher softness scores for meat loaf within just the 0°F in 24 hour rate (Table 112).

In a comparison of immediately following freezing with various treatment combinations after nine months storage, only the +20°F storage temperature in combination with the 0°F initial storage temperature produced higher softness scores in meat loaf (Table 113). After twelve months there were no treatment combinations that differed in softness scores from that found right after freezing; however, for product stored initially at -10°F, the meat loaf from product finally stored at -10°F was softer than loaf from product stored at 0°F (Table 114). Also, at twelve months, freezing rate was involved with initial-final storage temperatures, temperature abuse and immediately after freezing values for softness (Table 115). However, no differences were detected by HSD.

Connective tissue values as detected in meat loaf are presented next. It would not be expected that the variables of the project design would greatly influence connective tissue scores. The general table (Table 116) provides the sensory panel scores. Following nine months of storage, more

Table 110. Effect of various storage time comparisons on sensory scores for softness in meat loaf made from bulk ground beef

Evaluation Time	
Immediately following freezing, 1 day	9 months
5.21 ± .094b	5.56 ± .094a
Immediately following freezing, 1 day	12 months[c]
5.30 ± .02a	5.01 ± .02b
Immediately following freezing, 1 day	12 months[d]
5.21 ± .12a	5.01 ± .12b
9 months	12 months
5.71 ± .12a	5.01 ± .07b

ab Means on the same line with different letters are different ($P<.05$).
Mean ± S.E.

[c]Includes just 0°F in 24 and 48 hr freezing rates.

[d]Includes just temperature abused product.

Table 111 Interaction of storage time (six, nine mos.) and rate of freezing on sensory scores for softness of meat loaf

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
6	5.50 ± .08abc	5.24 ± .08bc	5.49 ± .08abc	5.43 ± .08abc
9	5.89 ± .15a	5.88 ± .15a	5.66 ± .15ab	5.05 ± .15c

abc Any mean comparisons with the same letters are not different (P>.05). Mean ± S.E.

Table 112. Interaction effect of storage time (nine, twelve months) and freezing rate on sensory scores for softness in meat loaf made from bulk ground beef

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	5.85 ± .17a	5.63 ± .17abc	5.67 ± .17ab	4.91 ± .17d
12	4.70 ± .097d	5.03 ± .097cd	5.18 ± .097bcd	5.15 ± .097bcd

abcd Any mean comparison with different letters is different ($P<.05$); Mean ± S.E.

Table 113. Interaction effect of storage time (immediately following freezing, nine months) temperature abuse, initial storage temperature, final storage temperature on sensory scores for softness in meat loaf made from bulk ground beef

Immediately following freezing, 1 day	Temperature abuse		9 Months Storage					
		Initial Storage temperature, °F =	-10			0		
		Final Storage temperature, °F =	-10	0	20	-10	0	20
5.21 ± .090bc	T		5.64 ± .14abc	5.43 ± .14abc	5.68 ± .14abc	5.16 ± .14c	5.76 ±.14ab	5.90 ± .14a
	N		--	--	5.49 ± .13abc	--	--	5.42 ± .14abc

abc Any mean comparison with the same letters is not different (P>.05); Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 114. Effect of storage time (immediately following freezing, twelve months) on sensory scores for softness in meat loaf made from bulk ground beef

		12 months storage			
	Initial Storage temperature, °F =	-10		0	
Immediately following freezing, 1 day	Final Storage temperature, °F =	-10	0	-10	0
$5.21 \pm .11$ab		$5.29 \pm .11$a	$4.78 \pm .11$b	$4.97 \pm .11$ab	$5.01 \pm .11$ab

ab Means on the same line with the same letters are not different ($P>.05$); Mean $\pm$ S.E.

Table 115. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, final storage temperature, temperature abuse and freezing rate on sensory scores for softness in meat loaf made from bulk ground beef[a]

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Temperature abuse	Freezing rate, hours to 0°F: 24	Freezing rate, hours to 0°F: 48
Immediately after freezing, 1 day				5.35 ± .20	5.25 ± .20
12 months	-10	-10	T	4.71 ± .20	5.46 ± .20
		0	T	4.72 ± .20	4.76 ± .20
		+20	N	5.68 ± .20	4.96 ± .20
	0	-10	T	4.65 ± .20	4.86 ± .20
		0	T	4.71 ± .20	5.03 ± .20
		+20	N	5.57 ± .20	5.04 ± .20

[a]Interaction significant ($P<.05$) by analysis of variance but not by HSD. Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 116. General table illustrating sensory scores for connective tissue amount in meat loaf throughout storage times and according to final storage temperature and freezing rate - no statistical analyses

Evaluation time, months	Final storage temperature, °F	Freezing Rate, hours to 0°F			
		24	48	72	96
Before freezing		6.57 ± .64	6.75 ± .53	6.61 ± .49	6.42 ± .63
After freezing 1 day		6.71 ± .53	6.58 ± .59	6.65 ± .47	6.64 ± .44
6 months	-10	6.79 ± .36	6.99 ± .29	6.65 ± .48	6.68 ± .52
	0	6.94 ± .30	6.85 ± .46	6.59 ± .55	6.54 ± .60
	+20 T	6.86 ± .43	6.92 ± .46	6.76 ± .44	6.62 ± .53
9 months	-10	7.05 ± .42	7.12 ± .38	7.08 ± .43	6.96 ± .26
	0	7.07 ± .18	7.08 ± .36	6.98 ± .40	6.89 ± .17
	+20 T	7.08 ± .13	7.19 ± .36	6.58 ± .62	6.89 ± .17
	+20 N	6.95 ± .27	7.04 ± .26	6.98 ± .19	6.83 ± .39
12 months	-10	6.82 ± .37	6.86 ± .47	6.85 ± .46	7.00 ± .00
	0	6.80 ± .37	6.88 ± .43	6.91 ± .44	6.97 ± .26
	+20 T	6.82 ± .42	6.93 ± .48	--	--

Mean ± S.D. T = temperature abused, N = not temperature abused.

connective tissue was found in meat loaf made from product frozen to 0°F in 72 and 96 hours compared to loaf from product frozen to 0°F in 48 hours (Table 117). More advanced storage seemed to result in less connective tissue being detected by panelists with the exception of nine vs twelve months (Table 118). After nine months of storage, regardless of initial storage temperature, less connective tissue was found in meat loaf formulated from bulk ground beef stored at 0 or -10°F final storage temperature (Table 119). In comparing nine with twelve month storage values (Table 120), less connective tissue was observed at nine months, if product had originally been frozen to 0°F in 24 or 48 hours.

General values for juiciness are presented in Table 121. Not many or large differences or trends were noted, although slightly more juiciness was detected in meat loaf following nine months storage. Following twelve months of storage, more juiciness were observed in meat loaf processed from bulk ground beef stored both initially and finally at -10°F vs bulk product held at 0°F initially and -10°F finally (Table 122). Overall, a considerable reduction in juiciness scores occurred between nine and twelve months (Table 123). After nine months of storage only, product stored initially and finally at 0°F produced different scores for juiciness (higher) than those found immediately after freezing (Table 124).

Nine months of storage yielded higher scores for juiciness than six months if bulk ground beef was originally frozen to 0°F in either 24 or 48 hours (Table 125). While a four-way interaction was detected after twelve months of storage (which included values noted right after freezing) the only significant difference noted was the lower values found for loaf processed from bulk product stored twelve months, initially stored at 0°F, finally stored at -10°F and originally frozen to 0°F in 24 hours vs loaf

Table 117. Effect of freezing rate on sensory scores for connective tissue amount in meat loaf made from bulk ground beef following nine months storage

Freezing rate, hours to 0°F			
24	48	72	96
7.04 $\pm$ .042ab	7.11 $\pm$ .070a	6.90 $\pm$ .053b	6.89 $\pm$ .070b

ab Means on the same line with different letters are different ($P<.05$); Mean $\pm$ S.E.

Table 118. Effect of various storage time comparisons on sensory scores for connective tissue amount in meat loaf made from bulk ground beef

Evaluation time	
Immediately following freezing, 1 day	9 months
6.65 ± .051b	6.96 ± .051a
6 months	9 months
6.77 ± .018b	6.93 ± .032a
Immediately following freezing, 1 day	12 months[c]
6.65 ± .065b	6.86 ± .065a
Immediately following freezing, 1 day	12 months[d]
6.65 ± .047b	6.88 ± .047a
9 months	12 months
7.04 ± .033a	6.86 ± .019b

ab Means on the same line with different letters are different ($P<.05$).
Means ± S.E.
[c]Includes only 0°F in 24 and 48 hr freezing rates.
[d]Includes only temperature abused product.

Table 119. Effect of storage time (immediately following freezing, nine months) on sensory scores for connective tissue amount in meat loaf made from bulk ground beef

Immediately following freezing, 1 day	Temperature abuse		9 Months Storage					
		Initial Storage temperature, °F =	-10			0		
		Final Storage temperature, °F =	-10	0	20	-10	0	20
6.65 $\pm$ .049b	T		7.09 $\pm$ .077a	7.00 $\pm$ .077a	6.87 $\pm$ .077ab	7.00 $\pm$ .077a	6.98 $\pm$ .077a	6.93 $\pm$ .077ab
	N		--	--	6.90 $\pm$ .069ab	--	--	6.91 $\pm$ .077ab

ab Any mean comparison with the same letters is not different (P>.05); Mean $\pm$ S.E.
T = temperature abused, N = not temperature abused.

Table 120. Interaction effect of storage time (nine, twelve months) and rate of freezing on sensory scores for connective tissue amount in meat loaf

Evaluation time, months	Freezing rate, hours to 0°F 24	48	72	96
9	7.05 ± .04ab	7.11 ± .04a	6.95 ± .04abc	6.94 ± .04abc
12	6.81 ± .03c	6.87 ± .03bc	6.88 ± .04bc	6.97 ± .03abc

abc Any mean comparisons with the same letters are not different (P>.05).
Mean ± S.E. Product stored at +20°F not included.

Table 121. General Table illustrating sensory scores for juiciness in meat loaf made from bulk ground beef throughout storage time according to final storage temperatures and rate of freezing - no statistical analysis[a]

Evaluation Time	Final Storage Temperature, °F	Freezing rate, Hours to 0°F 24	48	72	96
Before freezing		4.47 ± .82	4.66 ± .92	4.89 ± .84	4.70 ± .79
After freezing					
1 Day		4.68 ± 1.08	4.51 ± .81	4.86 ± .79	4.27 ± 1.23
6 months	-10	4.67 ± 1.05	4.65 ± .91	4.72 ± .88	4.79 ± .68
	0	4.54 ± .97	4.76 ± 1.02	4.77 ± .87	4.91 ± .90
	+20T	4.54 ± 1.05	4.46 ± 1.07	5.12 ± .84	4.84 ± .92
9 months	-10	5.14 ± .73	4.77 ± 1.37	4.79 ± 1.42	5.14 ± 1.07
	0	5.34 ± 1.05	5.66 ± 1.05	5.17 ± 1.30	4.80 ± 1.17
	+20T	5.27 ± .72	5.20 ± 1.17	4.76 ± 1.21	4.77 ± .84
	+20N	5.08 ± 1.02	5.04 ± .92	4.62 ± .72	4.89 ± .93
12 months	-10	4.36 ± .78	4.68 ± .72	4.72 ± .77	4.94 ± .76
	0	4.30 ± .61	4.52 ± .56	4.58 ± .62	5.12 ± .84
	+20T	4.66 ± .73	4.61 ± .61	--	--

[a] Means ± S.D. T=temperature abused, N=not temperature abused.

Table 122. Interaction of final storage temperature and initial storage temperature on sensory scores for juiciness in meat loaf made from bulk ground beef stored twelve months

Final Storage Temperature, °F	Initial Storage Temperature, °F	
	-10	0
-10	4.77 ± 0.10a	4.29 ± 0.10b
0	4.43 ± 0.10ab	4.40 ± 0.10ab
+20 N	4.46 ± 0.10ab	4.71 ± 0.10ab

ab Any mean comparison with the same letters is not different ($P<.05$).
Mean ± S.E. Only 0°F in 24 and 48 hr freezing rates included.
N = not temperature abused.

Table 123. Effects of various storage time periods on sensory scores for juiciness in meat loaf made from bulk ground beef

Evaluation Time	
Immediately following freezing, 1 day	12 months[c]
4.58 ± .09b	4.64 ± .09a
Immediately following freezing, 1 day	12 months[d]
4.59 ± .10b	4.52 ± .10b
9 months	12 months
5.22 ± .09a	4.52 ± .05b

ab Means on the same line with different letters are different ($P<.05$).
Mean ± S.E.

[c]Includes just temperature abused product.

[d]Includes just 0°F in 24 and 48 hr product.

Table 124. Effect of storage time (immediately following freezing, nine months) on sensory scores for juiciness in meat loaf made from bulk ground beef

Immediately following freezing, 1 day	Temperature abuse		9 Months Storage					
		Initial Storage temperature, °F =	-10			0		
		Final Storage temperature, °F =	-10	0	20	-10	0	20
4.58 ± .11b	T		5.11 ± .17ab	5.02 ± .17ab	4.87 ± .17ab	4.75 ± .17ab	5.35 ± .17a	4.99 ± .17ab
	N		--	--	4.73 ± .15ab	--	--	4.85 ± .17ab

ab Any mean comparison with the same letters is not different (P>.05); Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 125. Interaction of storage time (six, nine mos) and rate of freezing on sensory scores for juiciness of meat loaf

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
6	4.58 ± .09c	4.62 ± .09c	4.87 ± .09bc	4.85 ± .09bc
9	5.07 ± .13ab	5.41 ± .13a	4.90 ± .13bc	4.73 ± .13bc

ab Any mean comparisons with the same letters are not different (P>.05).
Mean ± S.E.

made from product initially stored at -10°F, finally stored at 0°F, frozen to 0°F in 96 hours and stored for twelve months (Table 126). An interaction involving twelve months storage with values from immediately following freezing and including +20°F final storage was noted to be significant ($P<.05$) by analysis of variance, but not be HSD (Table 127). Between nine and twelve months, meat loaf made from 0°F in 24 hour freezing rate only, was lower in juiciness (Table 128).

The next general area of the report concentrates on various components of weight loss throughout the project. Table 129 depicts the change in weight from before freezing until after thawing or what we might classify as "total project loss." For the other products, total project loss has included the losses in weight associated with cooking and subsequent cooling of cooked product. In the case of bulk ground beef, which is utilized as meat loaf, there are so many added ingredients that weight loss beyond thawing of bulk ground beef would not be realistic to evaluate. There were some indications that "total project loss" was higher for bulk product frozen to 0°F in 96 hours.

Various comparisons of immediately following freezing with advancements in storage time produced more weight loss with increasing storage time (Table 130). However, following nine months of storage, only product initially stored at 0°F and finally at -10°F had more "total project loss" than that determined just following freezing without storage (Table 131). After twelve months, only one initial-final storage temperature combination (-10°F initial and final) yielded similar weight losses to that found right after freezing (Table 132). When just the 0°F in 24 and 48 hour freezing rates were compared at twelve months (thus

Table 126. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, final storage temperature and rate of freezing on sensory scores for juiciness in meat loaf made from bulk ground beef

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day			4.68 ± .15ab	4.50 ± .15ab	4.86 ± .15ab	4.28 ± .15ab
12 months	-10	-10	4.61 ± .15ab	4.93 ± .15ab	4.96 ± .15ab	4.87 ± .15ab
		0	4.39 ± .15ab	4.46 ± .15ab	4.38 ± .15ab	5.06 ± .15a
	0	-10	4.13 ± .15b	4.44 ± .15ab	4.48 ± .15ab	5.01 ± .15ab
		0	4.21 ± .15ab	4.58 ± .15ab	4.63 ± .15ab	5.05 ± .15a

ab Any mean comparisons with the same letters are not different ($P<.05$); Mean ± S.E.

Table 127. Effect of storage time (immediately following freezing, twelve months) on sensory scores for juiciness in meat loaf made from bulk ground beef[a]

Immediately following freezing, 1 day		12 Months Storage					
	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
4.59 ± .089		4.77 ± .089	4.43 ± .089	4.56 ± .089	4.29 ± .089	4.40 ± .089	4.71 ± .089

[a]Differences significant (P<.05) by analysis of variance, but not by HSD. Mean ± S.E. T = temperature abused, N = not temperature abused.

Table 128. Interaction of storage time (nine, twelve mos.) and rate of freezing on sensory scores for juiciness in meat loaf made from bulk ground beef

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	5.25 ± .21a	5.31 ± .21a	5.07 ± .21ab	4.77 ± .21ab
12	4.34 ± .12b	4.60 ± .12ab	4.61 ± .12ab	5.00 ± .12ab

ab Any mean comparisons with same letters are not significant (P>.05).
Mean ± S.E.

Table 129. General table illustrating percent change in weight of bulk ground beef from just before freezing until after thawing throughout storage and according to final storage temperature and freezing rate - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F: 24	48	72	96
Before freezing					
Immediately following freezing, 1 day		-1.17 ± .62	- .94 ± .13	-1.24 ± 1.17	-1.54 ± .38
6 months	-10	-2.89 ± .58	-2.76 ± 1.60	-1.54 ± .92	-3.71 ± .74
	0	-2.97 ± .90	-2.72 ± .71	-1.20 ± .52	-4.28 ± .58
	20	-2.88 ± .91	-3.02 ± 1.05	-1.38 ± .49	-3.76 ± 1.02
9 months	-10	-2.11 ± 1.21	-2.34 ± 1.88	-1.86 ± .33	-3.49 ± .33
	0	-2.09 ± 1.37	-2.84 ± .48	-1.78 ± .04	-2.73 ± .61
	20 T	-3.01 ± 1.69	-2.51 ± .051	-2.29 ± .47	-3.07 ± .70
	20 N	-2.67 ± .38	-2.52 ± .10	-1.59 ± .58	-2.95 ± .40
12 months	-10	-2.42 ± .13	-2.37 ± 1.20	-2.22 ± 1.10	-3.32 ± .82
	0	-3.09 ± .72	-3.11 ± .77	-1.66 ± .77	-3.28 ± 1.27
	20 N	-2.27 ± .56	-3.12 ± .93	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 130. Effect of various storage time comparisons on percent change in weight of bulk ground beef from just before freezing until after thawing

Evaluation times	
Immediately following freezing, 1 day	6 months
-1.22 ± .29b	-2.76 ± .29a
Immediately following freezing, 1 day	9 months
-1.22 ± .28b	-2.43 ± .28a
Immediately following freezing, 1 day	12 months[c]
-1.22 ± .36b	-2.69 ± .36a
Immediately following freezing, 1 day	12 months[d]
-1.06 ± .45b	-2.73 ± .45a

ab Differences between means on the same line significant ($P<.05$). Mean ±. S.E.
[c]Includes just temperature abused product.
[d]Includes just 0°F in 24 and 48 hr freezing rates.

Table 131. Effect of storage time (immediately following freezing, nine months) on percent change in weight of bulk ground beef from just before freezing until after thawing

Immediately following freezing, 1 day	Temperature abuse	9 Months					
	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10	0	20	-10	0	20
-1.22 ± .26b	T	-1.81 ± .41ab	-2.76 ± .36ab	-2.77 ± .36ab	-3.14 ± .41a	-1.91 ± .41ab	-2.70 ± .36ab
	N	--	--	-2.06 ± .36ab	--	--	-2.26 ± .40ab

ab Any mean comparison with the same letters is not different (P>.05). Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 132. Effect of storage time (immediately following freezing, twelve months) on percent change in weight from just before freezing until after thawing for bulk ground beef

		12 Months Storage			
	Initial Storage temperature, °F =	-10		0	
Immediately following freezing, 1 day	Final Storage temperature, °F =	-10	0	-10	0
-1.22 ± .32b		-2.25 ± .32ab	-2.67 ± .32a	-2.92 ± .32a	-2.90 ± .37a

ab Means on the same line with the same letters are not different (P>.05); Mean ± S.E.

permitting the inclusion of +20°F final storage temperature) with "total project loss" immediately following freezing, only the product initially and finally stored at 0°F possessed more weight loss than that noted immediately following freezing (Table 133).

Values for change in weight from just before until just after freezing are presented in Table 134. Obviously, values assigned at various storage times are not really affected by storage but are rather additional data for the same variable. It would appear that the least increase in weight just during freezing occurred for the product frozen to 0°F in 96 hours.

Longer storage time and the use of +20°F storage temperature resulted in more weight loss during storage, although values were generally low (Table 135). The use of +20°F storage produced more weight loss than the other two temperatures, even following six months storage (Table 136). Also, at six months, just within the 0°F initial storage temperature, bulk product originally frozen to 0°F in 24 hours had more weight loss than bulk ground beef frozen to 0°F in 72 hours (Table 137). Following nine months of storage, the 0°F in 24 hour freezing rate produced more loss in weight than the 0°F in 48 hour rate (Table 138). This was also true following twelve months of storage (Table 139). In an interaction involving six-nine months of storage with freezing rate, the aforementioned differences at nine months were between 0°F in 24 vs 48 hours, while at six months, the big difference was the weight gain (experienced at all storage temperatures) for bulk ground beef frozen to 0°F in 72 hours (Table 140). Six months of storage produced less weight loss than nine months when the initial and final temperature were both -10°F or 0°F (Table 141).

Table 133. Effect of storage time (immediately following freezing, twelve months) on percent change in weight of bulk ground beef from just before freezing until after thawing

		12 Months Storage					
	Initial Storage temperature, °F =	-10			0		
Immediately following freezing, 1 day	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
$-1.06 \pm .42$b		$-2.18 \pm .42$ab	$-2.73 \pm .42$ab	$-2.80 \pm .42$ab	$-2.61 \pm .42$ab	$-3.47 \pm .42$a	$-2.58 \pm .42$ab

ab Means on the same line with the same letters are not different ($P > .05$); Mean $\pm$ S.E.

Table 134. General table illustrating the percent change in weight from just before to just after freezing throughout storage and according to final storage temperature and rate of freezing for bulk ground beef - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F: 24	48	72	96
Immediately after freezing, 1 day		+.06 ± .005	+.04 ± .08	-.01 ± .005	-.002 ± .002
6 months	-10	+.04 ± .03	+.02 ± .03	+.04 ± .09	+.02 ± .03
	0	+.01 ± .02	+.04 ± .03	+.08 ± .07	+.009 ± .03
	+20	+.07 ± .04	+.02 ± .02	+.02 ± .02	-.01 ± .06
9 months	-10	+.08 ± .10	+.03 ± .05	+.04 ± .03	-.01 ± .07
	0	+.09 ± .10	+.05 ± .03	+.03 ± .01	+.02 ± .03
	+20 T	+.04 ± .06	+.05 ± .03	+.03 ± .02	+.01 ± .08
	+20 N	+.054 ± .05	+.007 ± .07	+.03 ± .05	+.01 ± .07
12 months	-10	+.09 ± .06	+.02 ± .03	+.03 ± .01	-.06 ± .08
	0	+.07 ± .06	+.02 ± .02	+.06 ± .04	-.03 ± .03
	+20 N	+.10 ± .03	+.01 ± .02	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 135. General table illustrating the percent change in weight during frozen storage for bulk ground beef throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses[a]

Evaluation Time	Final storage Temperature, °F	Freezing rate, hours to 0°F 24	48	72	96
Before freezing		---	---	---	---
After freezing		---	---	---	---
6 months	-10	-0.081 ± 0.054	-0.007 ± 0.048	+0.012 ± 0.045	-0.064 ± 0.095
	0	-0.063 ± 0.026	-0.045 ± 0.016	+0.069 ± 0.054	-0.049 ± 0.032
	+20T	-0.16 ± 0.025	-0.085 ± 0.059	+0.0024 ± 0.064	-0.063 ± 0.048
9 months	-10	-0.15 ± 0.065	-0.067 ± 0.046	-0.10 ± 0.047	-0.062 ± 0.052
	0	-0.20 ± 0.064	-0.089 ± 0.058	-0.085 ± 0.067	-0.10 ± 0.056
	+20T	-0.18 ± 0.038	-0.11 ± 0.079	-0.16 ± 0.060	-0.15 ± 0.079
	+20N	-0.37 ± 0.049	-0.11 ± 0.036	-0.18 ± 0.045	-0.11 ± 0.046
12 months	-10	-0.15 ± 0.088	-0.018 ± 0.077	-0.027 ± 0.068	-0.080 ± 0.059
	0	-0.14 ± 0.058	-0.079 ± 0.069	-0.076 ± 0.050	-0.13 ± 0.28
	+20N	-0.27 ± 0.038	-0.095 ± 0.023	---	---

[a]Mean ± SD, T=temperature abused, N=not temperature abused

Table 136. Effect of final storage temperature on change in weight of bulk ground beef during six months of storage

Final Storage Temperature, °F		
-10	0	+20
-.035 ± .011b	-.022 ± .010b	-.075 ± .010a

ab Means with different letters are different ($P < .05$). Mean ± S.E.

Table 137. Interaction effect of initial storage temperature and rate of freezing on percent change in weight of bulk ground beef stored six months

Initial Storage Tempera- ture, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	-.081 ± .017ab	-.020 ± .017abc	+.015 ± .017bc	-.023 ± .017abc
0	-.120 ± .020a	-.072 ± .017abc	+.040 ± .017c	-.095 ± .017ab

[abc]Any mean comparisons with the same letters are not different (P > .05)
Mean ± S.E.

Table 138. Effect of rate of freezing on percent change in weight of bulk ground beef stored nine months

Freezing rate, hours to 0°F			
24	48	72	96
-.226 ± .033a	-.094 ± .033b	-.132 ± .033ab	-.104 ± .034ab

ab Means on the same line with the same letters are not different (P>.05). Mean ± S.E. Includes both temperature and non-temperature abused product stored at +20°F.

Table 139. Effect of freezing rate on percent change in weight of bulk ground beef through twelve months of storage

Freezing rate, hours to 0°F	
24	48
-.188 ± .021a	-.064 ± .019b

ab Difference significant ($P < .05$) between means. Mean ± S.E. Includes +20°F non-temperature abused product.

Table 140. Interaction effect of storage time (six, nine mos) and rate of freezing on percent change in weight of bulk ground beef during storage

Evaluation Time, months	Freezing rate, hours to 0°F 24	48	72	96
6	-.091 ± .017b	-.046 ± .015b	+.028 ± .015c	-.059 ± .015b
9	-.178 ± .015a	-.088 ± .015b	-.116 ± .015ab	-.103 ± .015b

ab Any mean comparisons with the same letter are not different ($P > .05$).
Mean ± S.E.

Table 141 Interaction effect of final storage temperature, storage time (six, nine months) and initial storage temperature on percent change in weight of bulk ground beef during storage

Final Storage Temperature, °F	Evaluation Time, months	Initial Storage Temperature, °F -10	0
-10	6	+.002 ± .018c	-.059 ± .022abc
	9	-.101 ± .018ab	-.092 ± .018abc
0	6	-.024 ± .018bc	-.021 ± .018bc
	9	-.083 ± .018abc	-.153 ± .018a
+20	6	-.059 ± .018abc	-.092 ± .018abc
	9	-.145 ± .018a	-.151 ± .018a

abc Any mean comparisons with the same letter are not different ($P > .05$).
Mean ± S.E.

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Including and combining both the weight changes in freezing and those of storage are shown in Table 142. An increase in storage time and an elevation in storage temperature raised the weight losses. After six months of storage, the increase in the weight found for product frozen to 0°F in 72 hours made it different from other rate-temperature combinations (Table 143). Following six, nine and twelve months of storage, +20°F final storage temperature resulted in a significant ($P<.05$) increase in weight loss (Table 144). Less weight was lost following twelve months of storage, if the bulk product had originally been frozen to 0°F in 48 hours rather than 0°F in 24 hours (Table 145). The 0°F in 72 hour freezing rate produced an increase in weight following six months in comparison to its counterpart at nine months (Table 146). A complex five-way interaction was detected for weight loss of bulk ground beef from before freezing until after storage (Table 147); however, only a few significant ($P<.05$) differences were noted.

Percent thaw loss is presented next. Generally, the greatest reduction in weight loss during thawing occurred for product originally frozen to 0°F in 96 hours, with the least being for bulk ground beef frozen to 0°F in 72 hours (Table 148). After nine months of storage, bulk ground beef initially frozen to 0°F and finally to -10°F had more thaw loss than product, thawed immediately following freezing (Table 149). At twelve months of storage, all initial-final storage temperature combinations evaluated at that time (with the exception of -10°F initial and final) had more thaw loss than that reported right after freezing (Table 150).

The next series of tables presents information regarding cooking loss and evaporative and drip components of cooking loss. Since so many added

Table 142. General table illustrating the percent change in weight from just before freezing until just after storage for bulk ground beef throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses[a]

Evaluation Time	Final storage Temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		---	---	---	---
Immediately After freezing		---	---	---	---
6 months	-10	-.016 ± .043	+.013 ± .060	+.050 ± .096	+.040 ± .084
	0	-.049 ± .032	-.010 ± .035	+.146 ± .085	+.040 ± .034
	+20	-.086 ± .020	-.063 ± .056	+.027 ± .085	+.074 ± .009
9 months	-10	-.067 ± .054	-.041 ± .049	-.063 ± .028	-.069 ± .040
	0	-.104 ± .036	-.036 ± .041	-.057 ± .069	-.086 ± .059
	+20T	-.141 ± .030	-.055 ± .055	-.131 ± .069	-.132 ± .102
	+20N	-.097 ± .040	-.119 ± .054	-.152 ± .044	-.098 ± .025
12 months	-10	-.063 ± .033	-.001 ± .061	+.008 ± .073	-.144 ± .108
	0	-.077 ± .057	-.057 ± .055	-.016 ± .024	-.167 ± .306
	+20N	-.150 ± .052	-.089 ± .017	---	---

[a]Mean ± S.D. T=temperature abused, N= not temperature abused

Table 143. Interaction effect of initial storage temperature and rate of freezing on percent change in weight from before freezing until after storage for bulk ground beef following six months storage

Initial Storage Temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	-.051 ± .017a	+.012 ± .017ab	+.055 ± .017b	-.038 ± .017a
0	-.050 ± .017a	-.053 ± .017a	+.094 ± .017b	-.064 ± .017a

ab Any mean comparisons with the same letters are not different (P>.05).
Mean ± S.E.

Table 144. Effect of final storage temperature at various storage periods on percent change in weight of bulk ground beef from before freezing until after storage

Storage Time months	Final Storage Temperature, °F		
	-10	0	20
6	+.002 ± .01b	+.012 ± .01b	-.049 ± .01a
9	-.06 ± .011b	-.071 ± .011b	-.11 ± .011a[c] -.12 ± .011a[d]
12	-.032 ± .015b	-.067 ± .015ab	-.12 ± .015a[d]

ab Means on the same line with the same letters are not different (P>.05). Mean ± S.E.

[c]Temperature abused product.

[d]Not temperature abused product.

Table 145. Effect of freezing rate on percent change in weight of bulk ground beef from just before freezing until after twelve months storage

Freezing Rate, hours to 0°F	
24	48
-.097 ± .012a	-.049 ± .012b

ab Difference between means significant ($P<.05$).
Mean ± S.E.

Table 146. Interaction effect of storage time (six, nine months) and freezing rate on percent change in weight of bulk ground beef from before freezing until after storage

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
6	-.05 ± .014ab	-.02 ± .014b	+.074 ± .014c	-.051 ± .014ab
9	-.10 ± .014a	-.044 ± .014ab	-.083 ± .014ab	-.096 ± .014a

abc Any mean comparison with the same letters is not different (P>.05); Mean ± S.E.

Table 147. Interaction effect of initial storage temperature, final storage temperature, temperature abuse, storage time (nine, twelve months) and freezing rate on percent change in weight of bulk ground beef from just before freezing until after storage

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Temperature abuse	Freezing rate, hours to 0°F: 24	Freezing rate, hours to 0°F: 48
9	-10	-10	T	-.04 ± .02ab	-.003 ± .02ab
12				-.07 ± .02ab	+.010 ± .02b
9	-10	0	T	-.13 ± .02ab	-.03 ± .02ab
12				-.05 ± .02ab	-.09 ± .02ab
9	-10	+20	N	-.07 ± .02ab	-.13 ± .02ab
12				-.17 ± .02a	-.08 ± .02ab
9	0	-10	T	-.10 ± .02ab	-.08 ± .02ab
12				-.05 ± .02ab	-.01 ± .02b
9	0	0	T	-.08 ± .02ab	-.04 ± .02ab
12				-.10 ± .02ab	-.02 ± .02ab
9	0	+20	N	-.13 ± .02ab	-.11 ± .02ab
12				-.12 ± .02ab	-.10 ± .02ab

ab Any mean comparisons with the same letters are not different (P>.05). Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 148. General table illustrating percent change in weight of bulk ground beef from just after storage until after thawing throughout storage times and according to final storage temperature and freezing rate - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing					
Immediately following freezing, 1 day					
6 months	-10	-2.48 ± .63	-2.10 ± 1.80	-1.29 ± .22	-2.95 ± .69
	0	-2.47 ± 1.03	-1.88 ± .90	- .32 ± .48	-3.60 ± .72
	20	-2.13 ± 1.08	-2.16 ± 1.15	- .17 ± 1.07	-2.62 ± 1.34
9 months	-10	-1.78 ± 1.13	-1.29 ± 1.37	-2.17 ± 1.42	-3.64 ± 1.18
	0	-1.60 ± 1.25	-1.86 ± .53	- .87 ± .89	-2.50 ± .97
	20 T	-2.17 ± 1.79	-1.07 ± 1.07	-1.28 ± .81	-2.97 ± 2.07
	20 N	- .62 ± .54	-1.64 ± .37	- .47 ± .59	-2.89 ± .84
12 months	-10	-1.94 ± .096	-1.41 ± 1.45	-1.37 ± .97	-2.21 ± 1.24
	0	-2.23 ± .31	-2.22 ± .78	- .93 ± .69	-2.11 ± 1.10
	20 N	-1.19 ± .67	-1.77 ± 1.17	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 149. Effect of storage time (immediately following freezing, nine months) on percent change in weight of bulk ground beef from just after storage until after thawing

Immediately following freezing, 1 day	Temperature abuse	Initial Storage temperature, °F = / Final Storage temperature, °F =	9 Months					
		Initial Storage temperature, °F =	-10			0		
		Final Storage temperature, °F =	-10	0	20	-10	0	20
-1.24 ± .25b	T		-1.86 ± .40ab	-2.78 ± .36ab	-2.80 ± .36ab	-3.17 ± .40a	-2.01 ± .40ab	-2.78 ± .36ab
	N		--	--	-2.10 ± .35ab	--	--	-2.30 ± .39ab

ab Any mean comparison with the same letters is not different (P>.05). Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 150. Effect of storage time (immediately following freezing, twelve months) on percent change in weight of bulk ground beef from after storage until after thawing

Immediately following freezing, 1 day		12 Months Storage			
	Initial Storage temperature, °F =	-10		0	
	Final Storage temperature, °F =	-10	0	-10	0
-1.24 ± .32b		-2.29 ± .32ab	-2.72 ± .32a	-2.92 ± .32a	-2.92 ± .37a

ab Means on the same line with the same letters are not different (P>.05); Mean ± S.E.

Table 151. General table illustrating the percent cooking loss for meat loaf made from bulk ground beef throughout storage and according to final storage temperature and freezing rate - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F 24	48	72	96
Before freezing		15.47 ± 1.66	15.15 ± 1.62	17.10 ± 2.30	12.85 ± 1.56
Immediately following freezing, 1 day		12.96 ± 1.60	17.29 ± .33	15.39 ± 1.25	14.78 ± 1.74
6 months	-10	14.65 ± 1.91	14.99 ± 1.18	15.94 ± 1.03	14.83 ± 1.55
	0	15.39 ± 3.13	14.89 ± .86	16.42 ± .39	15.33 ± 1.72
	20	15.17 ± 1.89	15.76 ± 1.34	15.87 ± .86	14.78 ± 1.76
9 months	-10	14.79 ± 2.34	14.76 ± .11	17.10 ± .87	15.84 ± .23
	0	14.05 ± .38	13.76 ± .79	16.11 ± .095	15.02 ± .62
	20 T	15.03 ± .99	13.72 ± .46	17.66 ± .26	16.78 ± .79
	20 N	18.16 ± 2.07	16.34 ± .30	16.20 ± .26	17.35 ± .76
12 months	-10	13.62 ± 1.17	14.86 ± 1.61	15.79 ± .56	15.63 ± 1.09
	0	14.99 ± 1.56	15.57 ± .49	14.77 ± 1.12	16.05 ± 1.67
	20 N	15.66 ± .31	17.28 ± .58	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

ingredients were used in the manufacture of meat loaf, it may be unrealistic to relate differences in cooking loss properties to the variables evaluated in the study. Thus, only minimal discussion will be presented on these data.

Differences were noted due to freezing rate for cooking loss before and after freezing, but are probably due to variations in loaf manufacture (Table 152).

Drip loss in meat loaf increased slightly as storage time of bulk ground beef advanced, probably due to the fact that some of the moisture evaported during frozen storage, leaving less to be lost as evaporative loss during cooking (Table 158). At both before freezing (Table 159) and after nine months of storage (Table 160), product frozen to 0°F in 72 hours had greater drip loss in resultant meat loaf than many of the other freezing rates. Following twelve months of storage, the use of +20°F generated more drip loss in meat loaf than the use of -10°F final storage temperature (Table 163).

Six, nine and twelve months of storage increased the drip loss component compared to that recorded immediately following freezing (Table 164). Following six months of storage, bulk ground beef finally stored at 0°F regardless of initial temperature and product finally stored at +20°F and initially at 0°F had more drip loss in meat loaf than loaf obtained from bulk ground beef right after freezing (Table 165). All treatment combinations having -10° or +20°F as a final storage temperature following nine months, produced more drip loss in meat loaf than that noted right after freezing (Table 166). After twelve months of frozen storage, only the +20°F final storage temperature in combination with the -10°F initial

Table 152. Interaction of storage time (before freezing, after freezing) and rate of freezing on percent cooking loss for meat loaf made from bulk ground beef.

Evaluation Time	Freezing rate, hours to 0°F			
	24	48	72	96
Before Freezing	15.5 ± .65ab	15.2 ± .65ab	17.1 ± .65a	12.8 ± .65b
After Freezing 1-Day	13.0 ± .65b	17.3 ± .65a	15.4 ± .65ab	14.8 ± .65ab

ab Any mean comparisons with the same letter are not different (P > .05).
Mean ± S.E.

√

Table 153. Effect of final storage temperature on percent cooking loss for meat loaf made from bulk ground beef stored for nine months[a]

	Final storage temperature, °F		
Temperature abuse	-10	0	+20
T	15.8 ± .36	14.8 ± .36	15.6 ± .36
N			16.8 ± .35

a Differences significant by analysis of variance ($P<.05$) but means cannot be compared due to minimal numbers, Mean ± S.E., T = temperature abused, N = not temperature abused.

Table 154. Effect of rate of freezing on percent cooking loss for meat loaf made from bulk ground beef following twelve months of storage.

Freezing rate, hours to 0°F	
24	48
14.7 ± .291b	15.9 ± .291a

ab Differences between means significant ($P < .05$)
Mean ± S. E.

Table 155. Effect of initial storage temperature on cooking loss for meat loaf made from bulk ground beef following twelve months of storage

Initial Storage Temperature, °F	
-10	0
14.7 ± .255b	15.6 ± .255a

ab Difference between means significant ($P < .05$). Mean ± S.E.
Includes only temperature abused product.

√

Table 156. Effect of storage time (immediately following freezing, twelve months) on percent cooking loss in bulk ground beef made from meat loaf

Evaluation time	
Immediately following freezing, 1 day	12 months
15.13 ± .52b	15.33 ± .52a

ab Difference between means significant ($P<.05$). Mean ± S.E. Includes only 0°F in 24 and 48 hr freezing rates.

Table 157. Effect of storage time (immediately following freezing, twelve months) on percent cooking loss in meat loaf made from bulk ground beef

		12 Months Storage					
	Initial Storage temperature, °F =	-10			0		
Immediately following freezing, 1 day	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
15.13 ± .47ab		13.44 ± .47b	14.99 ± .47ab	16.44 ± .47a	15.04 ± .47ab	15.56 ± .47ab	16.51 ± .47a

ab Means on the same line with the same letters are not different (P>.05); Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 158. General table illustrating the percent drip loss during cooking for meat loaf made from bulk ground beef throughout storage and according to final storage temperature and freezing rate - no statistical analysis[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		6.19 ± 1.16	6.64 ± 1.09	7.03 ± .62	5.25 ± .61
Immediately following freezing, 1 day		5.18 ± 1.20	7.40 ± .45	7.15 ± 1.17	5.82 ± .91
6 months	-10	6.32 ± .62	7.10 ± .47	8.72 ± 1.01	6.98 ± .58
	0	7.52 ± 1.66	7.07 ± 1.39	8.56 ± .29	7.61 ± .69
	20	6.85 ± .59	7.46 ± 1.52	8.73 ± .41	6.76 ± .98
9 months	-10	8.56 ± 1.22	8.37 ± .32	9.06 ± .46	7.77 ± .21
	0	7.47 ± .34	6.55 ± .59	8.39 ± .019	6.77 ± .74
	20 T	7.86 ± .055	6.83 ± .049	9.15 ± .35	9.10 ± 1.65
	20 N	9.04 ± .71	8.41 ± .42	9.54 ± .69	8.53 ± .55
12 months	-10	6.71 ± 1.01	8.03 ± 1.11	8.34 ± .22	8.41 ± .98
	0	7.65 ± .58	8.00 ± .38	7.78 ± 1.07	8.04 ± .49
	20 N	8.10 ± .81	9.20 ± .89	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 159. Effect of rate of freezing on percent drip loss for meat loaf made from bulk ground beef before freezing.

Freezing rate, hours to 0°F			
24	48	72	96
6.19 ± .18ab	6.64 ± .18a	7.03 ± .18a	5.25 ± .18b

ab Means on the same line with the same letters are not different (P > .05)
Mean ± S.E.

Table 160. Effect of freezing rate on percent drip loss during cooking for meat loaf made from bulk ground beef following nine months storage

Freezing rate, hours to 0°F			
24	48	72	96
8.26 ± .28ab	7.47 ± .28b	9.42 ± .28a	8.04 ± .28b

ab Means on the same line with the same letters are not different ($P>.05$); Mean ± S.E.

Table 161. Effect of rate of freezing on percent drip loss for meat loaf made from bulk ground beef stored for twelve months

Freezing rate, hours to 0°F	
24	48
7.49 ± .25b	8.41 ± .25a

ab Difference significant between means ($P < .05$)
Means ± S.E.
Includes both temperature and nontemperature abused product

Table 162. Effect of initial storage temperature on percent drip loss for meat loaf made from bulk ground beef stored twelve months

Initial Storage Temperature, °F	
-10	0
7.51 ± .21b	8.21 ± .21a

ab Difference between means significant ($P < .05$). Mean ± S.E. Includes just temperature abused product.

Table 163. Effect of final storage temperature on percent drip loss for meat loaf made from bulk ground beef stored for twelve months

	Final Storage Temperature, °F		
Temperature Abuse	-10	0	+20
Y	7.37 ± .30b	7.83 ± .30ab	--
N	--	--	8.65 ± .30a

ab Any mean comparisons with the same letters are not different (P > .05).
Mean ± S.E. Y = temperature abused. N = not temperature abused.

✓

Table 164. Effect of various storage time comparisons on percent drip loss during cooking for meat loaf made from bulk ground beef

Evaluation times	
Immediately following freezing, 1 day	6 months
6.39 ± .28b	7.47 ± .28a
Immediately following freezing, 1 day	9 months
6.39 ± .33b	8.52 ± .33a
Immediately following freezing, 1 day	12 months[c]
6.39 ± .31b	7.87 ± .31a
Immediately following freezing, 1 day	12 months[d]
6.29 ± .45b	7.95 ± .45a

ab Means on the same line with different letters are different. Mean ± S.E.

[c]Includes only temperature abused product.

[d]Includes only 0°F in 24 and 48 hr freezing rates.

Table 165. Effect of storage time (immediately following freezing, six months) on percent drip loss during cooking in meat loaf made from bulk ground beef

Immediately following freezing, 1 day		6 Months Storage					
	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10	0	20	-10	0	20
6.39 $\pm$ .26b		7.26 $\pm$ .26ab	7.80 $\pm$ .26a	7.17 $\pm$ .26ab	7.30 $\pm$ .26ab	7.58 $\pm$ .26a	7.73 $\pm$ .26a

ab Means on the same line with the same letters are not different ($P<.05$); Mean $\pm$ S.E.

Table 166. Effect of storage time (immediately following freezing, nine months) on percent drip loss during cooking of meat loaf made from bulk ground beef

			9 Months					
		Initial Storage temperature, °F =	-10			0		
Immediately following freezing, 1 day	Temperature abuse	Final Storage temperature, °F =	-10	0	20	-10	0	20
6.39 ± .30b	T		8.43 ± .47a	7.71 ± .47ab	8.36 ± .47a	8.99 ± .47a	7.51 ± .47ab	8.85 ± .47a
	N		--	--	9.08 ± .42a	--	--	9.22 ± .47a

ab Any mean comparison with the same letters is not different (P>.05). Mean ± S.E.
T = temperature abused, N = not temperature abused.

storage temperature produced an increase in drip loss during cooking of meat loaf compared to that found right after freezing. This includes only the 0°F in 24 and 48 hour rates (Table 167). In comparing all freezing rates at twelve months (thus eliminating +20°F storage temperature), 0°F initial with both 0 and -10°F final storage temperatures generated more drip loss in meat loaf than that found right after freezing (Table 168).

General information concerning evaporative losses during cooking of meat loaf is shown in Table 169. No real trends are evident. At six, nine and twelve months, evaporative losses were less for meat loaf in contrast to that observed immediately following freezing (Table 170). This is, of course, opposite to what was observed following storage for drip loss. Evaporative losses were highest before freezing for product selected to be frozen to 0°F in 72 hours and after freezing for product frozen to 0°F in 48 hours (Table 171). Between six and nine months, evaporative losses declined only for product frozen to 0°F in 24 hours (Table 172). After twelve months of storage, only meat loaf processed from bulk product stored initially and finally at -10°F had less evaporative loss than product processed immediately following freezing (Table 174).

Percent moisture general values for raw bulk ground beef are presented in Table 175. Values were not greatly different, but there was a very slight trend for less moisture to be found in bulk product with advancements in storage time for the product originally frozen to 0°F in 72 or 96 hours. After six months of storage, more moisture was found in product originally frozen to 0°F in 24 hours than was the case for product frozen to 0°F in 48 and 96 hours (Table 176). After twelve months (Tables 178, 179), the 0°F in 24 hour rate had more moisture in the bulk product

Table 167. Effect of storage time (immediately following freezing, twelve months) on percent drip loss during cooking for meat loaf made from bulk ground beef

		12 Months Storage					
	Initial Storage temperature, °F =	-10			0		
Immediately following freezing, 1 day	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
6.29 ± .41b		6.87 ± .41b	7.48 ± .41ab	9.08 ± .41a	7.87 ± .41ab	8.17 ± .41ab	8.22 ± .41ab

ab Means on the same line with the same letters are not different (P>.05); Mean ± S.E. Includes only 0°F in 24 and 48 hr freezing rates.

Table 168. Effect of storage time (immediately following freezing, twelve months) on percent drip loss during cooking for meat loaf made from bulk ground beef

Immediately following freezing, 1 day		12 Months Storage			
	Initial Storage temperature, °F =	-10		0	
	Final Storage temperature, °F =	-10	0	-10	0
6.39 ± .28b		7.50 ± .28ab	7.54 ± .28ab	8.24 ± .28a	8.20 ± .28a

ab Means on the same line with the same letters are not different (P>.05); Mean ± S.E.
Includes only temperature abused product.

Table 169. General table illustrating the percent evaporative losses during cooking for meat loaf made from bulk ground beef throughout storage and according to final storage temperature and freezing rate - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		9.28 ± .83	8.51 ± 1.17	10.07 ± 2.64	7.60 ± .96
Immediately following freezing, 1 day		7.77 ± .85	9.90 ± .58	8.23 ± .35	8.96 ± .87
6 months	-10	8.32 ± 1.43	7.89 ± .74	7.23 ± .47	7.85 ± 1.03
	0	7.87 ± 1.67	7.81 ± 1.39	7.86 ± .40	7.72 ± 1.38
	20	8.32 ± 1.41	8.30 ± .77	7.14 ± 1.01	8.02 ± 1.22
9 months	-10	6.23 ± 1.12	6.39 ± .43	8.03 ± .41	8.07 ± .021
	0	6.58 ± .72	7.22 ± .20	7.72 ± .11	8.25 ± .12
	20 T	7.17 ± 1.05	6.89 ± .41	8.52 ± .61	7.67 ± .86
	20 N	9.12 ± 1.35	8.20 ± .12	6.66 ± .65	8.82 ± .21
12 months	-10	6.90 ± .64	6.83 ± .70	7.45 ± .45	7.23 ± .52
	0	7.34 ± 1.26	7.57 ± .51	6.99 ± .69	8.01 ± 1.19
	20 N	7.56 ± .59	8.09 ± .62	--	--

[a]Mean ± S.D. T = temperature abused, N = not temperature abused.

Table 170. Effect of various storage time comparisons on percent evaporative loss during cooking for meat loaf made from bulk ground beef

Evaluation times	
Immediately following freezing, 1 day	6 months
8.72 ± .32a	7.86 ± .32b
Immediately following freezing, 1 day	9 months
8.72 ± .32a	7.59 ± .32b
6 months	9 months
7.86 ± .09a	7.60 ± .15b
Immediately following freezing, 1 day	12 months[c]
8.84 ± .36a	7.38 ± .36b
Immediately following freezing, 1 day	12 months[d]
8.72 ± .29a	7.29 ± .29b

ab Difference between means on the same line is significant ($P<.05$).
Mean ± S.E.

[c]Includes only 0°F in 24 and 48 hr freezing rates.

[d]Includes only temperature abused product.

Table 171. Interaction of storage time (before freezing, after freezing) and rate of freezing on percent evaporative loss for meat loaf made from bulk ground beef.

Evaluation Time	Freezing rate, hours to 0°F 24	48	72	96
Before Freezing	9.28 ± .41ab	8.51 ± .41ab	10.07 ± .41a	7.60 ± .41b
After Freezing 1-Day	7.77 ± .41b	9.90 ± .41a	8.23 ± .29ab	8.96 ± .41ab

ab Any mean comparisons with the same letter are not different (P > .05).
Mean ± S.E.

√

Table 172. Interaction effect of storage time (six, nine months) and freezing rate on percent evaporative loss during cooking for meat loaf made from bulk ground beef

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
6	8.17 ± .02a	8.00 ± .17a	7.41 ± .17ab	7.86 ± .17a
9	6.44 ± .30b	7.46 ± .30ab	7.91 ± .30a	8.58 ± .30a

abc Any mean comparison with the same letters is not different (P>.05); Mean ± S.E.

Table 173. Effect of storage time (immediately following freezing, nine months) on percent evaporative loss during cooking of meat loaf made from bulk ground beef[a]

Immediately following freezing, 1 day	Temperature abuse		9 Months					
		Initial Storage temperature, °F =	-10			0		
		Final Storage temperature, °F =	-10	0	20	-10	0	20
8.72 ± .29	T		7.01 ± .47	7.30 ± .47	7.52 ± .47	7.71 ± .47	7.57 ± .47	7.20 ± .47
	N		--	--	8.15 ± .42	--	--	8.27 ± .47

[a]Differences significant (P<.05) by analysis of variance, but not by HSD. Mean ± S.E.
T = temperature abused, N = not temperature abused.

Table 174. Effect of storage time (immediately following freezing, twelve months) on percent evaporative loss during cooking for meat loaf made from bulk ground beef

		12 Months Storage					
	Initial Storage temperature, °F =	-10			0		
Immediately following freezing, 1 day	Final Storage temperature, °F =	-10T	0T	20N	-10T	0T	20N
8.84 $\pm$ .34a		6.56 $\pm$ .34c	7.51 $\pm$ .34abc	7.36 $\pm$ .34abc	7.17 $\pm$ .34bc	7.39 $\pm$ .34abc	8.29 $\pm$ .34ab

abc Means on the same line with different letters are different ($P<.05$); Mean $\pm$ S.E.
T = temperature abused, N = not temperature abused.

Table 175. General Table illustrating percent moisture in bulk ground beef throughout storage times and according to final storage temperature and freezing rate - no statistical analyses

Evaluation Time	Final storage Temperature, °F	Rate, Hours to 0°F 24	48	72	96
Before freezing		62.8 ± .24	61.3 ± .61	62.0 ± .44	62.4 ± .28
After freezing					
1 day		62.4 ± .43	61.3 ± .84	61.4 ± .64	61.6 ± .42
6 months	-10	62.4 ± .46	62.0 ± .87	62.1 ± .48	61.3 ± .81
	0	62.3 ± .47	61.8 ± 1.13	62.2 ± .48	61.5 ± .67
	+20	63.1 ± .94	61.4 ± .87	62.5 ± 1.00	60.4 ± 1.10
9 months	-10	62.4 ± 1.47	60.9 ± 1.20	61.1 ± 1.24	60.3 ± .96
	0	62.3 ± .91	60.7 ± 1.29	61.4 ± .28	60.4 ± .79
	+20 T	62.0 ± 1.48	61.3 ± 1.73	61.4 ± 1.34	59.9 ± 1.11
	+20 N	62.4 ± .42	61.5 ± .39	61.9 ± 1.64	60.9 ± .92
12 months	-10	62.4 ± .88	60.7 ± .78	61.0 ± 1.08	61.0 ± .70
	0	62.4 ± .43	61.2 ± .65	60.9 ± 1.07	61.2 ± .67
	+20 N	62.6 ± 1.0	61.2 ± .79	--	--

Mean ± S.D. T = temperature abuse N = not temperature abuse

Table 176. Effect of rate of freezing on percent moisture in bulk ground beef following six months of storage

Freezing rate, hours to 0°F			
24	48	72	96
62.63 ± .20a	61.74 ± .20bc	62.28 ± .20ab	61.08 ± .20c

abc Means on the same line with different letters are different ($P < .05$) Mean ± S.E.

✓

Table 177. Interaction of initial storage temperature, final storage temperature, and rate of freezing on percent moisture in bulk ground beef following nine months of storage

Initial Storage Temperature °F	Final Storage Temperature °F	Temperature Abuse	Freezing rate, hours to 0°F			
			24	48	72	96
-10	-10	Y	61.5 ± .41abcd	61.3 ± .41abcd	61.1 ± .41abcd	60.7 ± .41bcd
	0	Y	62.5 ± .41abc	60.8 ± .41abcd	61.3 ± .41abcd	60.6 ± .41bcd
	+20	Y	62.4 ± .41abcd	60.1 ± .41abcd	62.1 ± .41abcd	59.9 ± .41d
	+20	N	62.1 ± .41abcd	61.6 ± .41abcd	61.8 ± .41abcd	61.1 ± .41abcd
0	-10	Y	63.3 ± .41a	60.4 ± .41bcd	61.0 ± .41abcd	60.0 ± .41cd
	0	Y	62.1 ± .41abcd	60.6 ± .41bcd	61.5 ± .41abcd	60.3 ± .41bcd
	+20	Y	61.7 ± .41abcd	62.4 ± .41abcd	60.8 ± .41abcd	59.9 ± .41d
	+20	N	62.6 ± .41ab	61.3 ± .41abcd	62.0 ± .41abcd	60.7 ± .41bcd

abcd Any mean comparisons with the same letter are not different (P > .05). Mean ± S.E.
Y = temperature abused, N = not temperature abused

Table 178. Effect of rate of freezing on percent moisture in bulk ground beef following twelve months storage

Freezing rate, hours to 0°F			
24	48	72	96
62.4 $\pm$ .18a	60.9 $\pm$ .18b	61.0 $\pm$ .18b	61.1 $\pm$ .18b

[ab]Means on the same line with the same letters are not different ($P > .05$). Mean $\pm$ S.E. Includes no +20°F final temperature stored product.

Table 179. Effect of freezing rate on percent moisture in bulk ground beef following twelve months of storage

Freezing Rate, Hours to 0°F	
24	48
62.4 ± .19a	61.0 ± .19b

ab Means on the same line with different letters are different ($P<.05$). Mean ± S.E.

than all the other rates. After nine months, an interaction was noted (Table 177) involving initial and final storage temperature, temperature abuse, and freezing rate, but the major differences were really the higher moisture values in the 0°F in 24 hour product vs the 0°F in 96 hour product.

There was a slight reduction in moisture content of the bulk ground beef simply as a result of freezing (Table 180). Following nine months of storage, temperature abused bulk product finally stored at +20°F (regardless of initial storage temperature) had the least amount of moisture (Table 181). In an interaction involving six and nine months of storage, 0°F in 96 hour freezing rate often had less moisture than other rates at nine months but were more similar at six months to the other rates (Table 182).

As might be expected, the 0°F in 24 hour rate product had less fat (Table 183), although this lower value was only significant ($P<.05$) from the 0°F in 48 hour rate immediately following processing and before freezing (Table 184). Following six months of storage, the 0°F in 24 hour rate exhibited less fat in the bulk product than the 0°F in 48 and 96 hour rate (Table 185). After nine months of storage, bulk ground beef from the 0°F in 24 hour rate, stored initially at 0 and finally at -10°F had less fat than the 0°F in 48 hour rate product stored under the same temperature conditions (Table 186). After twelve months storage, 0°F in 24 hour product again had less fat than the other freezing rates (Tables 187, 188).

Values for expressible moisture (higher the value, the more expressible moisture) were highest for the 0°F in 24 hour product (Table 189). This product also had the highest total moisture. More expressible

Table 180. Percent moisture in bulk ground beef before and after freezing

Evaluation Time	
Before freezing	After freezing 1 day
62.1 ± .15a	61.7 ± .14b

ab Means on the same line with different superscripts are different ($P < .05$) Mean ± S.E.

✓

Table 181. Interaction effect of storage time (immediately before freezing, nine months), initial storage temperature, final storage temperature and rate of freezing on percent moisture in bulk ground beef

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Temperature abuse	Freezing rate, hours to 0°F			
				24	48	72	96
Immediately after freezing, 1 day				62.4 ± .40abcd	61.3 ± .40abcde	61.4 ± .40abcde	61.6 ± .40abcd
9 months	-10	-10	T	61.5 ± .40abcde	61.3 ± .40abcde	61.1 ± .40abcde	60.7 ± .40bcde
		0	T	62.5 ± .40abc	60.8 ± .40bcde	61.3 ± .40abcde	60.6 ± .40bcde
		+20	T	62.4 ± .40abcd	60.1 ± .40cde	62.1 ± .40abcde	59.9 ± .40e
		+20	N	62.1 ± .40abcde	61.6 ± .40abcde	61.8 ± .40abcde	61.1 ± .40abcd
	0	-10	T	63.4 ± .40a	60.4 ± .40bcde	61.0 ± .40abcde	60.0 ± .40de
		0	T	62.1 ± .40abcde	60.6 ± .40bcde	61.5 ± .40abcde	60.3 ± .40bcde
		+20	T	61.7 ± .40abcde	62.4 ± .40abcd	60.8 ± .40bcde	59.9 ± .40e
		+20	N	62.6 ± .40ab	61.3 ± .40abcde	62.0 ± .40abcde	60.7 ± .40bcde

abcde Any mean comparisons with the same letter are not different (P>.05); Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

Table 182. Interaction of initial storage temperature, final storage temperature, storage time (six, nine months) and rate of freezing on percent moisture in bulk ground beef.

Initial Storage Temperature °F	Final Storage Temperature °F	Evaluation Time, months	Freezing rate, hours to 0°F			
			24	48	72	96
-10	-10	6	62.5 ± .41abcd	62.1 ± .41abcde	62.3 ± .41abcde	60.9 ± .41abcde
		9	61.5 ± .41abcde	61.3 ± .41ab	61.1 ± .41abcde	60.7 ± .41bcde
-10	0	6	62.2 ± .41abcde	61.8 ± .41abcde	62.3 ± .41abcd	62.0 ± .41abcde
		9	62.5 ± .41abcd	60.8 ± .41ab	61.3 ± .41abcde	60.6 ± .41bcde
-10	+20	6	62.8 ± .41abc	61.6 ± .41abcde	62.6 ± .41abcde	60.7 ± .41abcde
		9	62.4 ± .41abcde	60.1 ± .41b	62.1 ± .41ab	59.9 ± .41e
0	-10	6	62.3 ± .41abcde	61.9 ± .41abcde	62.0 ± .41abcde	61.6± .41abcde
		9	63.4 ± .41a	60.4 ± .41b	61.0 ± .41ab	60.0 ± .41de
0	0	6	62.5 ± .41abcde	61.7 ± .41abcde	62.2 ± .41abcde	61.0 ± .41abcde
		9	62.1 ± .41abcde	60.6 ± .41ab	61.5 ± .41abcde	60.3 ± .41bcde
0	+20	6	63.4 ± .41a	61.3 ± .41abcde	62.4 ± .41abcde	60.2 ± .41cde
		9	61.7 ± .41abcde	62.4 ± .41ab	60.8 ± .41abcde	59.9 ± .41de

abcde Any mean comparisons with the same letters are not significant ($P>.05$). Mean ± S.E.

Table 183. General Table illustrating percent fat in bulk ground beef throughout storage times according to final storage temperature and freezing rate - no statistical analyses

Evaluation Time	Final storage Temperature, °F	Rate, Hours to 0°F 24	48	72	96
Before freezing		19.3 ± .29	20.8 ± .72	20.1 ± .45	19.6 ± .54
After freezing					
1 day		19.9 ± .40	20.4 ± 1.01	20.6 ± .73	20.4 ± .46
6 months	-10	19.6 ± .49	20.7 ± .99	20.3 ± .59	20.5 ± .74
	0	19.5 ± .43	20.9 ± .94	19.9 ± .35	20.6 ± .64
	+20	19.2 ± .91	20.9 ± .92	20.3 ± .91	21.5 ± 1.09
9 months	-10	19.1 ± 1.32	21.3 ± 1.23	20.5 ± 1.18	21.0 ± .95
	0	19.5 ± .89	21.3 ± 1.20	20.3 ± .47	21.0 ± .67
	+20 T	19.7 ± 1.38	20.7 ± 1.72	19.9 ± 1.07	21.2 ± 1.56
	+20 N	19.4 ± .41	20.8 ± .39	19.7 ± 1.62	20.6 ± .85
12 months	-10	19.6 ± .80	21.5 ± .73	20.8 ± 1.1	20.9 ± .60
	0	19.6 ± .27	21.1 ± .56	20.7 ± .79	20.7 ± .68
	+20 N	19.1 ± .94	21.1 ± .77	--	--

Mean ± S.D.

Table 184. Percent fat in bulk ground beef immediately following processing

Rate, hours to 0°F			
24	48	72	96
19.3 ± .21b	20.8 ± .21a	20.1 ± .21ab	19.6 ± .21ab

ab Means on the same line with different superscripts are different ($P < .05$) Mean ± S.E.

Table 185. Effect of freezing rate on percent fat in bulk ground beef following six months of storage

Rate, Hours to 0°F			
24	48	72	96
19.4 ± .20b	20.8 ± .20a	20.2 ± .20ab	20.9 ± .20a

ab Means on the same line with the same superscript are not different ($P > .05$) Mean ± S.E.

✓

Table 186. Interaction of initial storage temperature, final storage temperature, and freezing rate on percent fat in bulk ground beef following nine months of storage

Initial Storage Temperature °F	Final Storage Temperature °F	Temperature Abuse	Rate, hours to 0°F			
			24	48	72	96
-10	-10	Y	19.9 ± .44abc	20.9 ± .44abc	20.4 ± .44abc	20.7 ± .44abc
	0	Y	19.1 ± .44bc	21.1 ± .44ab	20.5 ± .44abc	20.7 ± .44abc
	+20	Y	19.5 ± .44abc	21.8 ± .44a	19.5 ± .44abc	21.0 ± .44abc
	+20	N	19.6 ± .44abc	20.7 ± .44abc	19.8 ± .44abc	20.5 ± .44abc
0	-10	Y	18.4 ± .44c	21.7 ± .44ab	20.6 ± .44abc	21.4 ± .44ab
	0	Y	19.9 ± .44abc	21.5 ± .44ab	20.2 ± .44abc	21.3 ± .44ab
	+20	Y	19.9 ± .44abc	19.6 ± .44abc	20.3 ± .44abc	21.4 ± .44ab
	+20	N	19.1 ± .44bc	20.8 ± .44abc	19.6 ± .44abc	20.7 ± .44abc

abc Means on the same line or same column with the same superscript are not different (P > .05) Mean ± S.E.

Y = Yes, N = No

Table 187. Effect of rate of freezing on percent fat in bulk ground beef following twelve months storage

Freezing rate, hours to 0°F			
24	48	72	96
19.6 ± .15b	21.3 ± .15a	20.8 ± .15a	20.8 ± .15a

[ab]Means on the same line with the same letters are not different ($P > .05$).
Mean ± S.E. Does not have any +20°F final temperature stored product.

Table 188. Effect of freezing rate on percent fat in bulk ground beef following twelve months storage

Freezing Rate, hours to 0°F	
24	48
19.47 ± .14b	21.14 ± .15a

ab Difference between means significant (P<.05); Mean ± S.E. Includes both temperature and non-temperature abused product.

Table 189. General table illustrating expressible moisture values for bulk ground beef throughout storage and according to final storage temperature and freezing rate - no statistical analyses[a]

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		.015 ± .0005	.012 ± .00076	.013 ± .0007	.013 ± .00067
Immediately after freezing, 1 day		.015 ± .0014	.011 ± .0003	.012 ± .00079	.012 ± .0019
6 months	-10T	.014 ± .0015	.014 ± .0011	.014 ± .0022	.012 ± .0011
	0T	.014 ± .0016	.014 ± .0018	.014 ± .0011	.014 ± .0016
	20T	.015 ± .0016	.013 ± .00074	.014 ± .0015	.012 ± .0031
9 months	-10T	.014 ± .00088	.014 ± .00098	.013 ± .0011	.014 ± .0014
	0T	.013 ± .0018	.013 ± .003	.013 ± .0018	.014 ± .0011
	20T	.014 ± .0032	.014 ± .00096	.014 ± .0011	.015 ± .00067
	20N	.015 ± .0015	.014 ± .0022	.013 ± .00093	.015 ± .0014
12 months	-10T	.014 ± .0016	.011 ± .0031	.013 ± .00073	.013 ± .0014
	0T	.013 ± .0012	.011 ± .0014	.014 ± .0019	.014 ± .0018
	20N	.014 ± .0018	.014 ± .0031	--	--

[a]Mean ± S.D.; T = Temperature abused; N = Not temperature abused.

moisture was found in the +20°F stored product compared to the -10°F product following twelve months storage (Table 190). Increases in storage time, somewhat surprisingly increased expressible moisture (Table 191). Between nine and twelve months, the amount of expressible moisture decreased in bulk ground beef frozen to 0°F in 48 hours (Table 193, 194).

Table 190. Effect of final storage temperature on expressible moisture values in bulk ground beef following twelve months of storage

Final storage temperature, °F		
-10T	0T	20N
.012 $\pm$ .00041b	.0122 $\pm$ .00041ab	.0137 $\pm$ .00047a

ab Means on the same line with the same letters are not different (P>.05); Mean $\pm$ S.E.

Table 191. Effect of various storage time comparisons on expressible moisture values for bulk ground beef

Evaluation time	
Immediately following freezing, 1 day	6 months
.012 $\pm$ .00063b	.014 $\pm$ .00063a
Immediately following freezing, 1 day	9 months
.012 $\pm$ .00055b	.014 $\pm$ .00055a

ab Means on the same line with different letters are different (P<.05); Mean $\pm$ S.E.

Table 192. Interaction effect of storage time (six, nine months) and rate of freezing on expressible moisture values in bulk ground beef[a]

Evaluation time, months	Freezing rate, hours to 0°F 24	48	72	96
6	.0141 ± .00039	.0136 ± .00039	.014 ± .00039	.0126 ± .00039
9	.0134 ± .00039	.0136 ± .00039	.0131 ± .00039	.0143 ± .00039

[a]Interaction effect significant ($P<.05$) by Analysis of Variance, but not by HSD; Mean ± S.E.

Ev
ti

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Table 193. Interaction effect of storage time (nine, twelve months) and rate of freezing on expressible moisture values for bulk ground beef

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	.0133 $\pm$ .00046a	.0135 $\pm$ .00046a	.0128 $\pm$ .00046ab	.0141 $\pm$ .00046a
12	.0134 $\pm$ .00046a	.0108 $\pm$ .00046b	.0133 $\pm$ .00046a	.0136 $\pm$ .00046a

ab Any mean comparison with the same letter is not different ($P<.05$); Mean $\pm$ S.E.

Table 194. Interaction effect of storage time (nine, twelve months) and rate of freezing on expressible moisture values for bulk ground beef

Evaluation time, months	Freezing rate, hours to 0°F	
	24	48
9	.0138 ± .00031a	.0137 ± .00031a
12	.0135 ± .00031a	.0115 ± .00031b

ab Any mean comparison with the same letter is not different (P>.05); Mean ± S.E.

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